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Proceedings of the International Billfish Symposium Kailua-Kona, Hawaii, 9-12 August 1972 Part 3. Species Synopses

RICHARD S. SHOMURA and FRANCIS WILLIAMS (Editors)

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Synopsis of Biological Data on Blue Marlin, *Makaira nigricans* Lacépède, 1802

L. R. RIVAS[1]

1 IDENTITY

1.1 Nomenclature

1.11 Valid name

Makaira nigricans Lacépède, 1802.

1.12 Objective synonymy

Tetrapturus herschelli Gray, 1838.
Tetrapturus amplus Poey, 1860.
Tetrapturus mazara Jordan and Snyder, 1901.
Makaira bermudae Mowbray, 1931.
Eumakaira nigra Hirasaka and Nakamura, 1947.
Makaira perezi de Buen, 1950.
Istiompax howardi Whitley, 1954.

1.2 Taxonomy

1.21 Affinities

Suprageneric

Phylum Chordata
Subphylum Vertebrata
Superclass Gnathostomata
Class Teleostomi
Subclass Actinopterygii
Order Perciformes
Suborder Xiphioidei
Superfamily Xiphioidae
Family Istiophoridae

Generic

Genus *Makaira* Lacépède, 1802.

Makaira Lacépède, 1802 (type species *Makaira nigricans* Lacépède, 1802).

Statement of generic concept: According to my interpretation, the black marlin, *indica,* should be placed in the genus *Makaira* in addition to *nigricans* (see 1.22 Taxonomic status). Therefore, the genus *Makaira* comprises only two species.

Subjective generic synonyms:

Tetrapturus (not of Rafinesque, 1810) Cuvier *in* Cuvier and Valenciennes, 1831 (type species *Tetrapturus indicus* Cuvier, 1832).
Machaera Cuvier, 1832 (type species *Machaera velifera* Cuvier, 1832 by monotypy).
Macaria Nardo, 1833 (amended spelling of *Makaira).*
Istiompax Whitley, 1931 (type species *Istiompax australis* Whitley, 1931, nomen nudum).
Eumakaira Hirasaka and Nakamura, 1947 (type species *Eumakaira nigra* Hirasaka and Nakamura, 1947).
Orthocraeros Smith, 1956 (type species *Makaira bermudae* Mowbray, 1931).

Diagnosis: Makaira is distinguished from all the other genera of the family Istiophoridae (*Istiophorus, Tetrapturus)* by the following characters:

Anterior height of first dorsal fin less than depth of body at origin of first dorsal fin. Second predorsal length 75 to 79% of body length. Precaudal vertebrae 11, caudal 13. Flesh pale. Maximum weight more than 682 kg (1,500 lb), often weighing more than 182 kg (400 lb), and usually more than 114 kg (250 lb).

Specific

Identity of type specimen: A sketch of a 365 kg (803 lb) *Makaira nigricans,* blue marlin, sent to Lacépède (see Morrow, 1959b).

Type locality: Ile de Ré, Bay of Biscay, France.

Diagnosis: Makaira nigricans is distinguished from *M. indica* by the following characters: pectoral joint flexible, the fin folding flat against the sides of body without breaking joint. Median ridge in isthmus present. Anterior height of first dorsal fin about equal to, or longer than distance between origin of first dorsal fin and insertion of pectoral fin. Lateral line not visi-

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ble externally, complex, forming a reticulate pattern covering sides of body (visible when large patch of skin is removed and dried). Dorsal spines 39 to 46, usually 41 to 43. Anal spines 14 to 17, usually 15 or 16. Pectoral rays 20 to 22, usually 21 or 22.

Material examined: Specimens studied and allocated to this species (as *Makaira ampla*) by me (Rivas, 1956) were examined in the field and discarded because of their large size. Records of measurements, counts, sex, gonad condition, and other characters for these and other specimens are in my files.

Subjective synonymy: See above under objective synonymy.

1.22 Taxonomic status

I have always held that *Makaira nigricans* constitutes a single pantropical species occurring in the Atlantic, Pacific, and Indian oceans (Rivas, 1956, as *M. ampla*). The same view was held by Royce (1957), Briggs (1960), Robins and de Sylva (1960), Jones and Silas (1964), and Morrow (1964). Recently, however, Nakamura, Iwai, and Matsubara (1968) have indicated that two forms are involved which they interpret as closely related but separate species. They consider *M. nigricans* as restricted to the Atlantic and *M. mazara* as occurring in the Indo-Pacific. The only evidence given by these authors is a slight difference in the lateral line pattern; however, it should be noted that the specimens they compared were of different sizes. I disagree with Nakamura et al. (1968) that two species are involved and maintain that there is only one pantropical species.

1.23 Subspecies

As a corrollary to the above discussion it may be indicated that several authors have considered the Atlantic and Indo-Pacific forms as subspecies. This has been discussed by Nakamura et al. (1968). At the present state of knowledge, however, no subspecific division should be considered.

1.24 Standard common names and vernacular names.

Standard common names: Blue marlin (English-speaking countries), Aguja de Casta (Cuba), Marlin azul (Mexico, Central America, Venezuela), Pieto (Madeira), Kurokajiki (Japan), lan fu yii (China), taketonga (New Zealand).

Vernacular names: Cuban black marlin (United States), Castero (Cuba), Katsuokui, Katokui, Kuroka, Kurokawa, Shiroka, Shirokajiki, Gemba (Japan), Njiachi (Okinawa).

1.3 Morphology

1.31 External morphology

For description of spawn, larvae, and adolescents, see 3.17, 3.22, 3.23.

Individual and ontogenetic variation: Data and comments on individual and ontogenetic variation (allometric growth) have been presented by Rivas (1956), Royce (1957), and Nakamura et al. (1968). Much more information is needed.

Geographic variation: As yet, information is not available to establish the extent of geographic variation (see also comments under 1.22 and 1.23 above). This also applies to the morphological definition of subpopulations.

1.32 Cytomorphology

Nothing is known about chromosome number and other aspects of the cytomorphology of this species.

1.33 Protein specificity

No information on comparative serology is available for this species.

2 DISTRIBUTION

2.1 Total Area

Geographic distribution: The geographic and seasonal distributions are fairly well known as the result of data published by Ueyanagi et al. (1970) and Mather, Jones, and Beardsley (1972) for the Atlantic Ocean and by Howard and Ueyanagi (1965) and Nakamura et al. (1968) for the Pacific Ocean.

In the Atlantic, the latitudinal range of blue marlin varies seasonally and extends from about lat. 45°N to about lat. 35°S. Monthly distribution of catches by Japanese longliners shows two main seasonal concentrations. One occurs from January through April, in the southwestern Atlantic, between lat. 5° and 30°S and the other from June through October, in the northwestern Atlantic, between lat. 10° and 35°N. May, November, and December appear to be transitional months. The species is less abundant in the eastern Atlantic where it occurs mostly off Africa between lat. 25°N and 25°S.

In the Pacific, the latitudinal range of the blue marlin is also seasonal and extends from about lat. 48°N to about lat. 48°S. As in the Atlantic, monthly distribution of catches by Japanese longliners shows two main seasonal concentrations. One center of concentration occurs from December through March, in the western and central South Pacific, between lat. 8° and 26°S, and the other from May through October,

in the western and central North Pacific, between lat. 2° and 24°N. In April and November the fish tend to concentrate in the equatorial Pacific between lat. 10°N and 10°S. As in the Atlantic, the blue marlin in the Pacific Ocean is less abundant towards the East. In the extreme eastern Pacific, off the continental coast, the fish usually occurs between lat. 23°N and 3°S. Kume and Joseph (1969b) indicate that blue marlin occur in heaviest concentrations at about lat. 20°S and west of long. 110°W, north of lat. 13°N; however, their relative abundance is quite low. Kume and Joseph (1969a) record longline catches along the Peruvian coast as far south as lat. 12°S.

In the Indian Ocean, the blue marlin is known to occur around Ceylon, Mauritius, and off the east coast of Africa (Morrow, 1959a, 1964). Off the east coast of Africa, between the equator and lat. 13°S, the blue marlin is apparently abundant during the southeast monsoon period, April to October (Merrett, 1971).

2.2 Differential Distribution

2.21 Spawn, larvae, and juveniles

Areas of occurrence and seasonal variations: Three larvae were reported by Gehringer (1956) from the western Atlantic off Georgia (lat. 30°57′N, long. 79°37′W). These were later identified as blue marlin larvae by Ueyanagi and Yabe (1959). Two postlarvae were recorded from Jamaica by Caldwell (1962). Eschmeyer and Bullis (1968) recorded four larvae and postlarvae from the western Atlantic (two off Cat Cay, Bahamas, one at lat. 32°06′N, long. 72°00′W and one at about 40 miles northest of Fort Pierce, Fla.). Bartlett and Haedrich (1968) recorded 85 larvae from off Brazil between Cabo de São Roque and lat. 26°S.

Ueyanagi and Yabe (1959) recorded about 400 larvae from the western Pacific, and Ueyanagi (1964) reported that 1,015 larvae had been collected in the Pacific. Ueyanagi et al. (1970) have given the seasonal distribution of larval blue marlin for the Atlantic.

2.22 Adults

Areas of occurrence and seasonal variations: In most areas within its range the occurrence of adult male marlin appears to be seasonal and in some regions there is also a seasonal variation by sex.

The seasonal variation and relative abundance of blue marlin in the northern Gulf of Mexico have been discussed by Nakamura and Rivas (1972). Off Puerto Rico the largest numbers of blue marlin have been caught during August, September, and October, and the smallest catches have been made in December (Erdman, 1962). In Hawaii, blue marlin catches are also highest in summer and lowest in winter (Royce, 1957; Strasburg, 1970).

Very large blue marlin, probably females, are reported to occur off the south coast of Jamaica in the summer while similar large fish are reported off the north coast in the winter (de Sylva, 1963). Nine blue marlin specimens taken in late December and early January from Jamaican waters were examined by me; all were males. Off Puerto Rico, males and females occur in about equal numbers in July and August; larger males tend to appear in May and there is a sudden increase of small males in September (Erdman, 1968).

In the eastern Pacific, extreme differences in sex ratios between certain regions suggest strongly the possibility that blue marlin segregate into distinct areal groups according to sex (Kume and Joseph, 1969b).

2.3 Determinants of Distribution Changes

Effects of ecological determinants: The distribution of the blue marlin is mostly confined to the tropics within the 24°C surface isotherms of both hemispheres, and is noted to shift northward and southward according to season. In the western Atlantic off the northeastern United States, blue marlin have been taken in waters with surface temperatures ranging from 23.9° to 28.3°C (Squire, 1962). Blue marlin catches were recorded at 47 longline stations occupied during the past 22 yr by National Marine Fisheries Service (NMFS) vessels in the Caribbean Sea, Gulf of Mexico, and off the southeastern United States; surface temperatures at these stations ranged from 21.7° (February) to 30.5°C (July).

In certain regions water masses and currents apparently affect the horizontal and seasonal distribution of the blue marlin. For example, in the northern Gulf of Mexico the occurrence of blue marlin seems to be controlled by the so-called "Loop Current." This current, an extension of the Caribbean Current, flows northward into the Gulf through the Yucatan Channel. Its northward extent is seasonal and reaches its maximum in the summer.

Water color also affects the occurrence of the blue marlin, at least in the northern Gulf of Mexico, where the fish shows preference for blue water (Nakamura and Rivas, 1972).

There is indication of a periodic fluctuation in abundance which is probably due to ecological interaction with other species of marlin. For example, within the fishing season (April to November) in the northern Gulf of Mexico, anglers tend to catch more blue marlin when the white marlin catch is lowest and vice versa (Nakamura and Rivas, 1972). A similar phenomenon was reported by Strasburg (1970) for the blue and striped marlins around Hawaii. Strasburg suggests that perhaps each responds to some environmental factor, such as temperature or food, in a way which excludes the other.

2.4 Hybridization

There are no records of hybridization for the blue marlin.

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

The species is heterosexual. No occurrence of hermaphrodism or intersexuality has been observed. Males and females are indistinguishable externally, but the females attain a much larger size than the males.

For the central Pacific, Royce (1957) indicated that females have been taken at weights greater than 727 kg (1,600 lb) whereas the largest male weighed only 99 kg (218 lb). Around Hawaii most of the males weigh between 45 and 91 kg (100 and 200 lb), whereas most of the females weigh between 91 and 227 kg (200 and 500 lb) (Strasburg, 1970). In Puerto Rico, the largest male examined by Erdman (1968) weighed 135 kg (297 lb) and the largest female 370 kg (814 lb). Data from the Japanese longline fishery show that males seldom exceed 116 kg (255 lb) and that most males weigh from 39 to 80 kg (85 to 175 lb). De Sylva (1963) recorded a 140-kg (308-lb) male from Bimini, Bahamas, and Strasburg (1970) recorded a 133-kg (293-lb) male from Hawaii. Of 30 blue marlin examined by me in the northwestern Atlantic, 18 were males weighing 46 to 94 kg (101 to 207 lb) and 12 were females weighing 59 to 277 kg (130 to 609 lb). Usually, a blue marlin heavier than 136 kg (300 lb) is a female.

According to de Sylva (1963) protandry, the condition whereby a fish begins its life as a male and subsequently changes into a female, has been considered for the blue marlin.

3.12 Maturity

The age at which sexual maturity is reached cannot be calculated because methods of age determination have not been developed. As already indicated, males are smaller than females and size has to be considered. The smallest sexually mature male reported by Erdman (1968) from Puerto Rico weighed 35 kg (76 lb) and the smallest ripe male reported from Jamaica by de Sylva (1963) weighed 44 kg (97 lb). Of 26 males from the central Pacific examined by Royce (1957) the smallest specimen found with milt in the central duct of the testes weighed 42 kg (93 lb). The smallest sexually mature male reported for the western Indian Ocean by Merrett (1971) weighed 41 kg (90 lb). The smallest sexually mature female reported by Erdman (1968) from Puerto Rico weighed 61 kg (135 lb) and the smallest mature female reported by Merrett (1971) from the western Indian Ocean weighed 47 kg (103 lb). Of 1,152 females studied by Kume and Joseph (1969b) from the eastern Pacific, the smallest specimens found in a condition believed to be near spawning were about 200 cm long (eye to fork; no weight given). The indications are, therefore, that males reach sexual maturity at a weight of 35 to 44 kg (76 to 97 lb) and females at 47 to 61 kg (103 to 135 lb).

3.13 Mating

Probably polygamous.

3.14 Fertilization

Evidence indicates that fertilization is external.

3.15 Gonads

The relation of gonad weight to body weight was determined by Erdman (1968) for 14 males and 15 females from Puerto Rico. Males weighed from 47 to 123 kg (103 to 270 lb) and their testes from 55 g to 2.4 kg (0.12 to 5.30 lb). Females weighed from 33 to 292 kg (72 to 643 lb) and their ovaries from 9.1 g to 6.5 kg (0.02 to 14.2 lb). The weight of the testes, as the percent of body weight, ranged from 0.10 to 2.30% in the males and from 0.03 to 3.60% in the females. According to Erdman less than 0.10% for the testes and ovaries corresponds to sexually immature individuals. In the males, 0.10% to less than 0.70% corresponds to the developing stage with few to many spermatocytes and few or no sperm. Prespawning stage corresponds to a range of 0.70% to less than 2.30% with many spermatocytes and many sperm. At the ripe stage the relative weight of the testes decreases to a range of 0.60% to less than 1.60% but with few or no spermatocytes and many sperm. At the postspawning stage, 0.10% to less than 0.20%, there are no spermatocytes but many sperm. In the females, 0.10% to less than 1.0% corresponds to the developing stage with oocytes and no ova or a few developing ones, but no easily visible eggs. The subripe stage corresponds to a range of 1.00% to less than 3.60% with advanced oocytes and pale-yellow eggs. At the ripe stage the weight of the ovaries decreases to less than 1.50% of body weight, but is still 1.00% or more, with advanced oocytes, transparent eggs, and some postovulatory follicles. At the postspawning stage, 0.50% to less than 1.00%, there are some atretic bodies, many empty follicles, and degenerating oocytes.

Krumholz (1958) gives a range of 0.80 to 1.90%, with an average of 1.43%, for the weight of testes in relation to body weight in blue marlin from the Bahamas.

The relationship between ovary weight and body length for 1,152 blue marlin from the eastern Pacific was given by Kume and Joseph (1969b). Ovary weights ranged from a few grams to 14 kg (31 lb) and lengths (eye to fork) from about 140 to about 338 cm. In the majority of specimens the ovaries weighed less than 1 kg (2.2 lb) and probably were not in a spawning condition.

The length of the gonads, as a percentage of body length, can be used as an index of sexual maturity of

the testes and ovaries. Of 12 females studied by me the range was 7.6 to 13.2% in five specimens; their ovaries were in a resting condition. In the other seven fish, the range was 16.7 to 20.8% and their ovaries were developing but not yet ripe. In five males studied, the range was 22.0 to 32.4% and their testes were all ripe with much milt running in the ducts. No males in the resting or developing stage were available for comparison.

There is no information available on fecundity.

3.16 Spawning

Mather et al. (1972) believe that the two widely separated concentrations of blue marlin in the western Atlantic represent separate spawning populations. They indicate that the evidence suggests that the blue marlin in the North Atlantic spawn mainly from July through September and those in the South Atlantic spawn in February and March. These authors further state that it is unlikely that a single population of blue marlin spawns at two widely separate locations at different times of the year.

According to Erdman (1968) the occurrence of ripe testes from May to November indicates a protracted spawning season for the blue marlin off Puerto Rico. He found females with well-formed eggs from late May to September and a female with flowing ripe eggs in September. Erdman assumes that July and August are the peak spawning months because during that period the sex ratio is nearly equal.

De Sylva (1963) suggested May and June as the spawning season for the blue marlin found in waters off Florida and Bahamas. He also stated that mature fish taken off Cape Hatteras in June appear to have been recent spawners and that females taken in September and October from Jamaican and Puerto Rican waters have long since spawned.

For the Pacific Ocean, information on spawning of the blue marlin was summarized by Howard and Ueyanagi (1965) and Strasburg (1970). From the occurrence of larvae, gonad condition, and sex ratio, spawning is assumed to take place between about lat. 20°N and 10°S throughout the year. During the summer season, however, spawning is assumed to take place in the broader latitudinal area bounded by lat. 30°N and 30°S. Males with freely flowing milt have been captured in the central Pacific from February to October, and May to July has been regarded as the spawning season in the Philippine area.

Kume and Joseph (1969b) indicated that in the southwestern portions of the eastern Pacific Ocean, blue marlin spawn primarily during the southern summer.

Among the blue marlin specimens examined by Royce (1957) from the central Pacific no ripe females were found, but a number of males had freely flowing milt in the gonads from February through October.

Off Puerto Rico, the annual average male:female sex ratio was 4:1 based on 328 specimens examined by Erdman (1968). As already indicated, the 47 specimens examined by him in July and August show a more nearly equal ratio of 25:22. Every September, there is a sudden increase in the catch of males and the ratio changes to 4.5:1.

Of 39 specimens examined by de Sylva (1963) in Jamaica during early October, 37 were males for a ratio of 18.5:1.

Nakamura and Rivas (1972) recorded sex ratios for the northern Gulf of Mexico during the sport fishing season (June through October) as follows. Off the mouth of the Mississippi River (South Pass) the male:female sex ratio was 1:5.6 in 1967, 1:7.7 in 1968, 1:4.8 in 1969, 1:8.0 in 1970, and 1:33 in 1971. Off northwest Florida the male:female sex ratio was 1:2.5 (Destin) and 1:2 (Panama City).

In the central Pacific, according to data presented by Royce (1957), the mean annual male:female sex ratio is 1.2:1.

3.17 Spawn

Subripe ova are opaque, white to yellow, and 0.3 to 0.5 mm in diameter. Transparent, spherical eggs flowing out of a ripe ovary measure 1 mm in diameter (Erdman, 1968).

3.2 Preadult Phase

3.21 Embryonic phase

There is no information on the embryonic phase.

3.22 Larval phase

Various workers have contributed to the still very incomplete knowledge of the larval and juvenile stages of the blue marlin. Their findings are summarized below.

Gehringer (1956) described three unidentified larvae 11.3, 21.0, and 45 mm long from the Atlantic. These were later identified as blue marlin larvae by Ueyanagi and Yabe (1959). These authors also described eight specimens, 2.8 to 23.2 mm in length, selected from about 400 larval blue marlin collected in the western Pacific. Caldwell (1962) described two postlarval blue marlin measuring 201.4 and 206 mm in length from Jamaica. Ueyanagi (1964) reported that as of that date 1,015 larval blue marlin, 3 to 33 mm (mostly under 7 mm), had been collected in the Pacific by the Nankai Regional Fisheries Research Laboratory. Eschmeyer and Bullis (1968) described three larval (33.5, 35.3, and 51.5 mm) and one postlarval (194.1 mm) blue marlin from the western Atlantic. Bartlett and Haedrich (1968) reported on 85 larval blue marlin, 4.9 to 32.0 mm long from the southwestern Atlantic.

In summary, larval stages are fairly well known

from about 3 to 52 mm. There is a gap between about 52 and 194 mm and another, at the postlarval and juvenile stages, between 206 and 846 mm. The latter, described by de Sylva (1958) is the smallest young stage known. Ueyanagi (1963) discussed methods of identification for larval blue marlin based on Indo-Pacific material.

3.23 Adolescent phase

As already discussed above, under 3.12, males weighing less than 35 kg (76 lb) and females weighing less than 47 kg (103 lb) have not reached sexual maturity. Individuals in this category, therefore, may be considered to be in the young stage or adolescent phase provided they are past the juvenile stage. Two specimens of young blue marlin, 846 and 1,320 mm in length (tip of lower jaw to fork) were described by de Sylva (1958) from the Bahamas and southeast Florida, respectively. The smaller specimen weighed 2.3 kg (5 lb) and the other 13.9 kg (30.5 lb).

3.3 Adult Phase (Mature Fish)

3.31 Longevity

Estimates of blue marlin age may be obtained from analyses of modal progressions in length and weight frequency. Also, the sex must be known since males are much smaller than females. No definite information on age is, as yet, available for the blue marlin.

3.32 Hardiness

As already discussed under 2.22, blue marlin have been taken at surface temperatures as high as 30.5°C (July) and as low as 21.7°C (February).

Individuals captured, tagged, and liberated appear to suffer no ill effects since a few have been recaptured after several months of freedom.

3.33 Competitors

There is no definite information on this subject but there are indications that in the Atlantic, the white marlin, *Tetrapturus albidus*, might compete with the blue marlin for food. In the Indo-Pacific, the striped marlin, *T. audax*, and the black marlin, *Makaira indica*, might compete with the blue marlin for food. To a lesser extent the sailfish, *Istiophorus platypterus*, and the spearfishes, *T. belone, T. pfluegeri, T. angustirostris*, and *T. georgii*, might also compete with the blue marlin for food.

3.34 Predators

My own observations agree with the well-known fact that sharks frequently attack hooked blue marlin especially if the fish is tired after a long fight. It is not known whether sharks will attack a free-swimming, healthy, blue marlin, but I have seen a mako shark attack, kill, and eat a free-swimming broadbill swordfish.

3.35 Parasites, diseases, injuries, and abnormalities

Parasites and diseases: On several occasions, I have observed ectoparasitic calgoid copepods on the head of fresh-caught blue marlin. Cressey and Lachner (1970) reported that the marlinsucker, *Remora osteochis*, occurs on the body and in the gill cavity of the blue marlin where they feed on ectoparasitic copepods. Their examination of marlinsucker stomachs revealed the presence of *Caligus* and *Pennella* on blue marlin. Ectoparasitic copepods do not seem to affect the physiology, behavior, or food value of the blue marlin. The copepods are apparently kept in check by the marlinsucker who maintains a symbiotic relationship with the blue marlin and acts as a "cleaner."

The trematode *Capsala poeyi* from the skin of the blue marlin has been reported from Cuba by Vigueras (1935), from the Gulf of Mexico by Manter (1954) and Koratha (1955), and from the Pacific by Iversen and Hoven (1958).

Stomach ulcers were found in 10 of 114 blue marlin examined by Iversen and Kelley (1974) in Hawaii. These ulcers were noncancerous and morphologically similar to gastric ulcers found in many mammals, including marine mammals. Iversen and Kelley believe that endoparasites or mechanical injury to the stomach lining, from sharply pointed food items, are the most likely cause.

Injuries and abnormalities: Some of the blue marlin specimens examined by me have had some scars or malformed fins or bills. On several occasions the tip of the bill has been broken off. From time to time sport fishermen have told me of seeing blue marlin without a bill, but I have not personally seen specimens with this abnormality. Moore (1950) reported a 248-kg (545-lb) blue marlin from Hawaii without a spear. The appearance of the specimen indicated that the spear had been lost by injury and there was no indication that the loss was at all recent. Moore also mentioned that the specimen was equal in condition to normal blue marlin and that apparently the spear is not necessary for natural and adequate feeding. He also remarked that according to the operators of the Honolulu market spearfishes without a spear had been observed before but that such occurrences were very rare.

Erdman (1957) recorded a blue marlin with the bill missing and healed at the point of rupture. The upper jaw was shorter than the lower but the fish had actually more food in its stomach than four other blue marlin captured the same day.

Broken bills in marlin are apparently caused by the pugnacity of these fishes, according to Smith (1956). He states that many floating bales of rubber with

broken tips of marlin bills in them were found in the Mozambique Channel and believes that marlin must deliberately charge floating or submerged objects possibly to secure food or from plain aggressiveness.

A blue marlin with a bent bill was reported by Ovchinnikov (1970) from off West Africa.

3.4 Nutrition and Growth

3.41 Feeding

According to data from the northern Gulf of Mexico presented by Nakamura and Rivas (1972) blue marlin rise to a surface trolled bait more often in the morning between the hours of 1000 and 1100 and least often between 1200 and 1300 (central standard time). There is agreement in this for both South Pass, La., and the northwest Florida areas. The South Pass data also show that, in the afternoon, there is another well-marked peak between 1500 and 1600 but the northwest Florida data show a steady decrease from 1400 on.

Many sport fishermen have told me that they have tried without success to raise marlin during the night by surface trolling. I have tried, also without success.

From the information discussed above, it may be tentatively concluded that blue marlin do not feed at the surface at night and that there is a marked feeding period in the morning between 1000 and 1100.

De Sylva (1963) stated that during the 1963 Jamaica International Fishing Tournament more marlin were raised in the afternoon between 1400 and 1600 than at any other time of day. His results, however, were given in terms of the number of fish raised during 2-h intervals as a percentage of the total number of fish raised. No data on the effort expended was given.

I have heard many discussions among sport fishing guides and anglers about whether or not the blue and other marlins use their bill in capturing prey. These discussions, however, refer mostly to prey in the form of artificial or natural dead baits trolled at the surface at a uniform speed, usually 4 to 8 knots. In my opinion, based on many years of observation, marlins do not use their bill when taking a trolled bait. The lateral thrusts of the bill, which appear to be aimed at hitting the bait, are apparently the result of rapid changes in direction of movement of the fish and/or the effect of its swimming motions when the bill and head are partly out of the water.

As to the use of the bill when the fish is pursuing free-swimming prey, there is, again, difference of opinion but the general concensus is that the bill is not generally used to stun the prey.

Ovchinnikov (1970) discussed the use of the bill by marlins and concluded that it is not of importance in the capture of food. As pointed out by Ovchinnikov and as discussed above under 3.35 *Injuries and abnormalities*, marlins without bills or with broken or malformed bills are as healthy as the normal fish.

The various incidents of fish, boats, and various other floating objects impaled by marlin bills cited in the literature are, in my opinion, accidents resulting from feeding. It is well known that small fish congregate under such floating objects and that a marlin, in attempting to catch a fish too close to the floating object, may accidently impale it with its bill.

Tinsley (1964) gives a detailed discussion on the use of the bill in the sailfish which could well apply to the blue and other marlins.

3.42 Food

The literature shows that the types of food eaten by the blue marlin vary somewhat with the region where they occur. It is also indicated that the blue marlin feeds at or near the surface and in deep water, and near shore as well as out in the open sea.

Stomachs of blue marlin contained mostly squid in the Philippine Sea (Nakamura, 1942), tunalike fishes in New Zealand (Baker, 1966) and the central Pacific (Royce, 1957), and dolphin (*Coryphaena*) and tunalike fishes, especially frigate mackerel (*Auxis*), in the Bahamas (Krumholz and de Sylva, 1958). On a volumetric basis, tunalike fishes constitute more than 85% of the diet in Hawaii (Strasburg, 1970). In Puerto Rico tunalike fishes, in both number and volume, were the chief food of the blue marlin examined by Erdman (1962). Frigate mackerel was the most frequent individual item, and whenever it occurred in abundance blue marlin fishing was better than average. De Sylva (1963) indicates that only a relatively few types of organisms are eaten by blue marlin in Jamaica, the tunalike fishes being the most important. In the northern Gulf of Mexico fishes, especially dolphin and scombrids, were the most important food items found in the stomachs of blue marlin (Nakamura and Rivas, 1972). In the tropical western Atlantic, Ovchinnikov (1970) indicates that the blue marlin feeds mostly on fishes and cephalopods.

The size range of the organisms eaten by the blue marlin is relatively large. Krumholz and de Sylva (1958) indicated that the overall range in length for fishes was from about 20 to 102 cm (about 8 to about 40 inches). One of the octopods was about 15 cm (about 6 inches) whereas the largest one was about 61 cm (about 24 inches) long. Erdman (1962) recorded from Puerto Rico a 135-kg (279-lb) blue marlin which had eaten a postlarval surgeonfish 38 mm long. He also mentioned a squid weighing up to 11 kg (23 lb) taken from the stomach of a blue marlin. Strasburg (1969) mentioned that a blue marlin was caught in Hawaii with a 29-kg (63-lb) bigeye tuna, *Thunnus obesus*, in its stomach. The marlin including the tuna weighed 340 kg (748 lb). Ovchinnikov (1970) reported from the Gulf of Guinea a 290-kg (638-lb) blue marlin

which had swallowed a bigeye tuna weighing about 50 kg (about 110 lb).

The blue marlin is known to feed at and near the surface, but there are indications that it may also feed in relatively deep water. Off Puerto Rico, deep-sea fishes, such as *Pseudoscopelus*, were found in blue marlin stomachs (Erdman, 1962). The deep-dwelling squirrelfish, *Holocentrus lacteoguttatus*, was found in Hawaiian blue marlin stomachs by Strasburg (1970).

3.43 Growth rate

There is very little information on growth rate although estimates could be obtained from analyses of modal progressions in length and weight frequencies. Royce (1957) presented data on weight frequency for central Pacific blue marlin but no modal progression can be ascertained. Kume and Joseph (1969b) presented and discussed data on the size composition of blue marlin in the eastern Pacific, but they could not estimate growth from progression of modal groups.

3.44 Metabolism

No information available.

3.5 Behavior

Feeding behavior is discussed above under 3.41. There is no information on reproductive behavior.

3.51 Migrations and local movements

Ovchinnikov (1970) mentioned that, in the western Atlantic, distribution by months indicate that the blue marlin shows a tendency to seasonal migrations. Mather et al. (1972) are of the opinion that longline catches have produced no evidence that the blue marlin moves between the northwestern and southwestern Atlantic. These authors believe that there may be two populations in the western Atlantic or that there may be a single population which is unavailable to the fishery while the fish are migrating between the areas.

In the northwestern Atlantic, 561 blue marlin have been tagged since 1955 and only 4 have been recaptured, all near their respective release points (Mather, 1971). Although these tag returns are inconclusive, it does indicate that meaningful information can be obtained if sufficient numbers of fish are tagged.

For the central Pacific, Royce (1957) stated that north of the equatorial area the seasonal occurrence of blue marlin suggests a northward summer movement followed by a return south in late autumn. Anraku and Yabuta (1959) considered blue marlin in the Pacific to be a single intermingling unit which moves to the southeastern Pacific during the southern summer and returns to the northwestern Pacific during the northern summer. In the southeastern Pacific, Suda and Schaefer (1965) postulated a "strong active migration" of blue marlin in the vicinity of lat. 20°S long. 120°W. Howard and Ueyanagi (1965) indicated that the blue marlin migrates between the North and South Pacific towards the southeast and northwest, respectively. Fish taking part in this seasonal migration are generally limited in size, 140 to 180 cm; a few larger fish over 200 cm also take part in the migration. This suggests differential migration by sex, migration activity being greater in males. Howard and Ueyanagi consider that migration between the North and South Pacific indicates shift of habitat in accordance with spawning and seasonal change of sea conditions.

In the Pacific Ocean, 170 blue marlin have been tagged from 1963 through 1970. There have been no recoveries to date.

Sonic tags have already proved useful in studies of migration and local movements. A blue marlin was tagged on 14 July in Hawaii 3.1 miles west of Keauhou (Yuen, Dizon, and Uchiyama, 1974). The tag was inserted at 0935 and the fish was tracked by the NMFS RV *Charles H. Gilbert* until 0800 the next morning. A temperature sensitive sonic tag was selected in order to also obtain information on the depth of the fish. During the tracking period, the fish moved to about 25 miles north of the point of release on an erratic course between the 183- and 549-m (100- and 300-fathom) isobaths. Calculated speeds of the fish ranged from 0.6 to 4.4 knots with an average of 1.6. Swimming depth varied from the surface to about 73 m (40 fathoms) but it was mostly in the upper 37 m (about 20 fathoms).

3.52 Schooling

According to published information, mostly in the sport fishing literature, the blue marlin has never been observed occurring in schools. Verbal reports from anglers and sport fishing guides and my own observations confirm this. Occasionally, two or three fish will rise simultaneously to baits trolled from a single boat which indicates a small aggregation but not what would be termed a school. Ovchinnikov (1970) states that, unlike the sailfish, the blue marlin does not form "accumulations" in coastal waters. He also reports that, in the open ocean, blue marlin rarely gather in schools but are usually found "scattered singly."

Data on composition of blue marlin stocks by size and sex are given by various workers for the Atlantic and the Indo-Pacific.

Royce (1957) recorded weight frequencies by month for 4,712 central Pacific blue marlin but the sex was not recorded. According to Strasburg (1970), Royce's data show that the weight distribution was wide in January when 45- to 136-kg (100- to 300-lb) fish dominated the catch. By April, heavier fish 136 to 227 kg (300 to 500 lb), presumably females, were more common. By June, smaller fish, presumably males,

were numerous. These small fish dominated the summer catch, reached a peak in September, and then slowly declined. By December, conditions were similar to January.

Erdman (1968) recorded weight frequencies for 263 males and 65 females taken in waters off Puerto Rico. His data show that both males and females reach a peak of abundance in September.

Kume and Joseph (1969b) recorded the length-frequency distribution for 3,595 blue marlin from the eastern Pacific. The length ranged from 100 to 340 cm (eye to fork) but most of the specimens fell between 150 and 250 cm. The frequency curve was bimodal; the dominant mode occurred at about 200 cm.

Ueyanagi et al. (1970) recorded the length composition of Atlantic blue marlin by sex, season, and area. Their data show that in the North Atlantic the predominant length for males was about 150 cm (eye to fork) during May to October and about 170 cm during November to April. The predominant length for females was about 210 cm during May to October and about 210 to 220 cm during November to April. In the equatorial Atlantic the predominant length for males was about 160 to 190 cm throughout the year, and for females about 230 to 240 cm during May to October and about 140 cm from November to April. In the South Atlantic the predominant length for males was about 240 cm from May to October and about 190 cm from November to April. The predominant length for females was about 210 to 290 cm from May to October and from November to April there were two modes at about 130 and 250 cm. Ueyanagi et al. (1970) data also show that males were usually more numerous than females in all areas and seasons. Of the 1,209 specimens studied by them 785 were males and 424 females.

Ovchinnikov (1970) gave the size composition by length and weight of 80 specimens of blue marlin from the Atlantic but the material was not segregated by sex. He states that the most common length ranges from 180 to 220 cm and the most common weight from 50 to 80 kg (110 to 176 lb), but his table shows a marked mode at 190 to 200 cm and at 20 to 30 kg (44 to 66 lb). Obviously, the weights are erroneous in the table.

Length and weight frequencies of total longline catches of blue marlin from the equatorial western Indian Ocean were presented by Merrett (1971). Males ranged from 150 to 200 cm in length (tip of lower jaw to fork) and from 43 to 114 kg (95 to 250 lb) in weight. Females ranged from 235 to 270 cm and from 191 to 270 kg (420 to 595 lb).

Additional data on composition of stocks by size and sex is given under 3.12 and 3.16. As already indicated, there is no information on age composition.

3.53 Responses to stimuli

Environmental stimuli: As already discussed under 2.22 and 3.22, the blue marlin normally occur in waters warmer than 24°C, but it has been found at surface temperatures as high as 30.5°C and as low as 21.7°C.

As to responses to light, Ovchinnikov (1970) stated that according to recent investigations, the epiphysis and contiguous regions of the diencephalon, have a very high light sensitivity in fishes. He also stated that ". . . in all billfishes the glandular structure of the diencephalon, the analogue of the epiphysis, is powerfully developed . . . ." In the blue marlin, as well as in the other istiophorids, the tissues overlying the diencephalon are transluscent and admit light into the brain cavity. The structures involved are similar to the pineal apparatus of tunas described by me (Rivas, 1953). As indicated by Ovchinnikow, it is assumed that the pineal apparatus of the blue marlin reacts to light and may serve for orientation during horizontal and vertical movements.

There is no information available on the responses of the blue marlin to mechanical and chemical stimuli.

Artificial stimuli: In the northern Gulf of Mexico various natural and artificial baits are used in the sport fishery for billfishes (Nakamura and Rivas, 1972). According to these authors, blue marlin prefer striped mullet, *Mugil cephalus*, over ballyhoo, *Hemiramphus brasiliensis*, and bonito strip. These are the three baits most frequently used in the northern Gulf where blue marlin have also been taken on artificial lures (Kona head, rubber squid, etc.). In taking a dead bait or artificial lure trolled at the surface it is not known whether blue marlin are responding to taste, smell, color, size, shape, or action. It is well known that, in the longline fishery, blue marlin are taken on various types of dead bait.

Electrical: No information available.

4 POPULATION

4.1 Structure

4.11 Sex ratio

See 3.16 and 3.52.

4.12 Age composition

No information available.

4.13 Size composition

See 3.12 for size at maturity and 3.52 for length and weight composition.

The largest blue marlin from the Atlantic Ocean officially recorded by the International Game Fish Association weighed 384 kg (845 lb) and measured 399 cm (157 inches) in total length with a girth of 180 cm

(71 inches). It was taken off St. Thomas, Virgin Islands.

According to a personal communication from an angler, a large blue marlin was taken in the northern Gulf of Mexico, off northwest Florida, several years ago. The stated total length was 427 cm (168 inches) and the girth was 203 cm (80 inches). The fish was not weighed because scales were not available but according to the measurements it must have weighed in the neighborhood of 455 kg (1,000 lb).

Cuban commercial fishermen operating off Havana have told me that, on several occasions, they have taken "casteros," blue marlin weighing over 455 kg (1,000 lb). These fish are taken well below the surface with "palangres," a gear similar to the longline but with fewer hooks.

The largest blue marlin from the Pacific Ocean officially recorded by the International Game Fish Association weighed 524 kg (1,153 lb) and measured 447 cm (176 inches) in total length with a girth of 185 cm (73 inches). It was taken off Guam. The former record weighed 505 kg (1,110 lb) and measured 419 cm (165 inches) in total length with a girth of 202 cm (79.5 inches). This fish was taken in the Indian Ocean off Mauritius.

Although not officially accepted as a world record because three anglers participated in the catch, the largest blue marlin known to date was caught in the Pacific Ocean off Waikiki Beach in the Hawaiian Islands. The fish weighed 820 kg (1,805 lb).

The length-weight relationships given in Figures 1 and 2 are based on 58 males and 104 females from the western Atlantic. A separate curve is given for each sex. Each curve was eye-fitted by joining the points of mean length and weight for the upper, middle, and lower thirds of the total range. The length was measured from the tip of the lower jaw to the fork of the tail (Rivas, 1956). The curves show that, on the average, males from about 190 to 220 cm in length weigh less than females in the same length range. Within this length range the mean weight of males is 77 kg (169 lb) and that of females 87 kg (191 lb). At lengths of less than about 190 cm and more than about 220 cm, the length-weight relationship is about the same for males and females.

Length-weight data for 7 juveniles, 90 males, and 24 females, mostly from Puerto Rico, were given in tabular form by Erdman (1968). Merrett (1971) presented length-weight relationships for about 16 specimens of blue marlin from the equatorial western Indian Ocean. Strasburg (1969) gave a length-weight curve for blue marlin from Hawaii covering a range of about 76 to 495 cm (30 to 195 inches; fork length from tip of bill) and about 750 kg (20 to 1,650 lb).

4.2 Abundance and Density (of Population)

4.21 Average abundance

There is no information available.

4.22 Changes in abundance

See 2.3 and 3.33.

4.23 Average density

There is no information available.

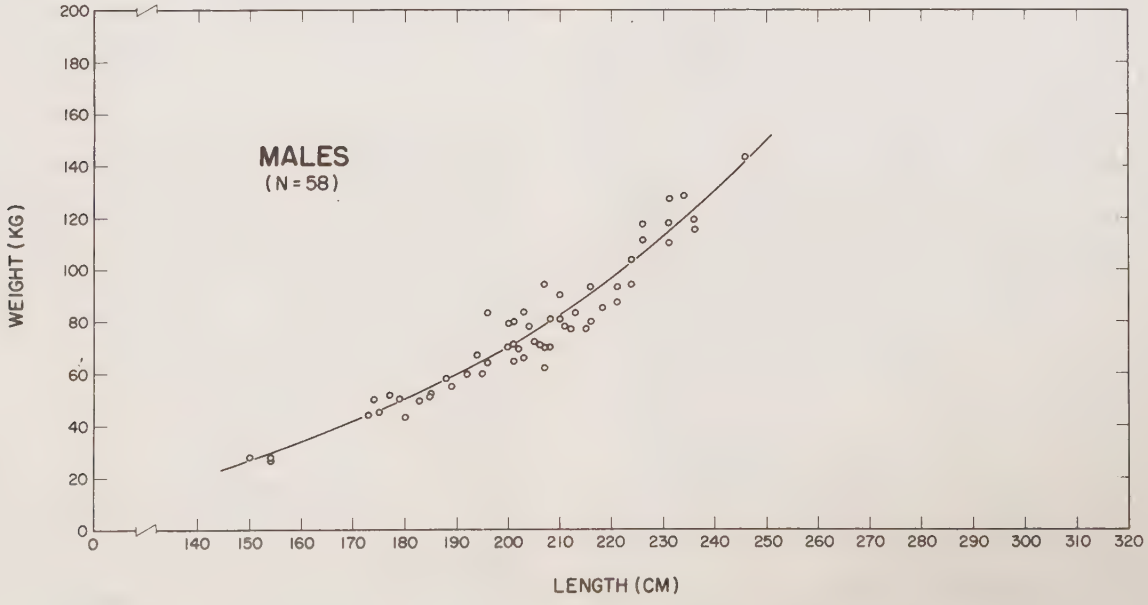

Figure 1.—The length-weight relationship of male blue marlin in the western Atlantic Ocean.

4.24 Changes in density

Ueyanagi et al. (1970) reported on the annual changes in longline catch and fishing effort for the Atlantic Ocean during 1958 through 1966. Until 1962, in the early stages of exploitation, the landings of blue marlin increased with the expansion of the fishery. After 1962, however, the catch per unit of effort showed a definite decrease. The relative abundance of blue marlin in 1965 is about one-fourth the level of 1962. The relative abundance of blue marlin began to decrease in the Atlantic Ocean after the fishing effort extended over virtually the entire distributional area of the species and after the annual landings exceeded about 80,000 fish.

Based on longline fishing data presented by Merrett (1971) for the western Indian Ocean, the relative abundance of the blue marlin decreased during the period covered by the study. The catch rate decreased from 0.204 fish per hundred hooks in 1964 to 0.020 fish in 1966.

For the blue marlin sport fishery in the northern Gulf of Mexico, Nakamura and Rivas (1972) used "number-of-fish-raised-per-hour-of-trolling" as an index of relative abundance. Their study only covered the 1971 fishing season (May through October) and the relative abundance, by weekly periods, varied from 0.012 to 0.130 fish-per-hour-of-trolling without any marked peaks.

See 2.1 and 2.3 for additional information on seasonal variation of stocks.

4.3 Natality and Recruitment

4.31 Reproduction rates

No information available.

4.32 Factors affecting reproduction

No information available.

4.33 Recruitment

No information available.

4.4 Mortality and Morbidity

4.41 Mortality rates

No information available.

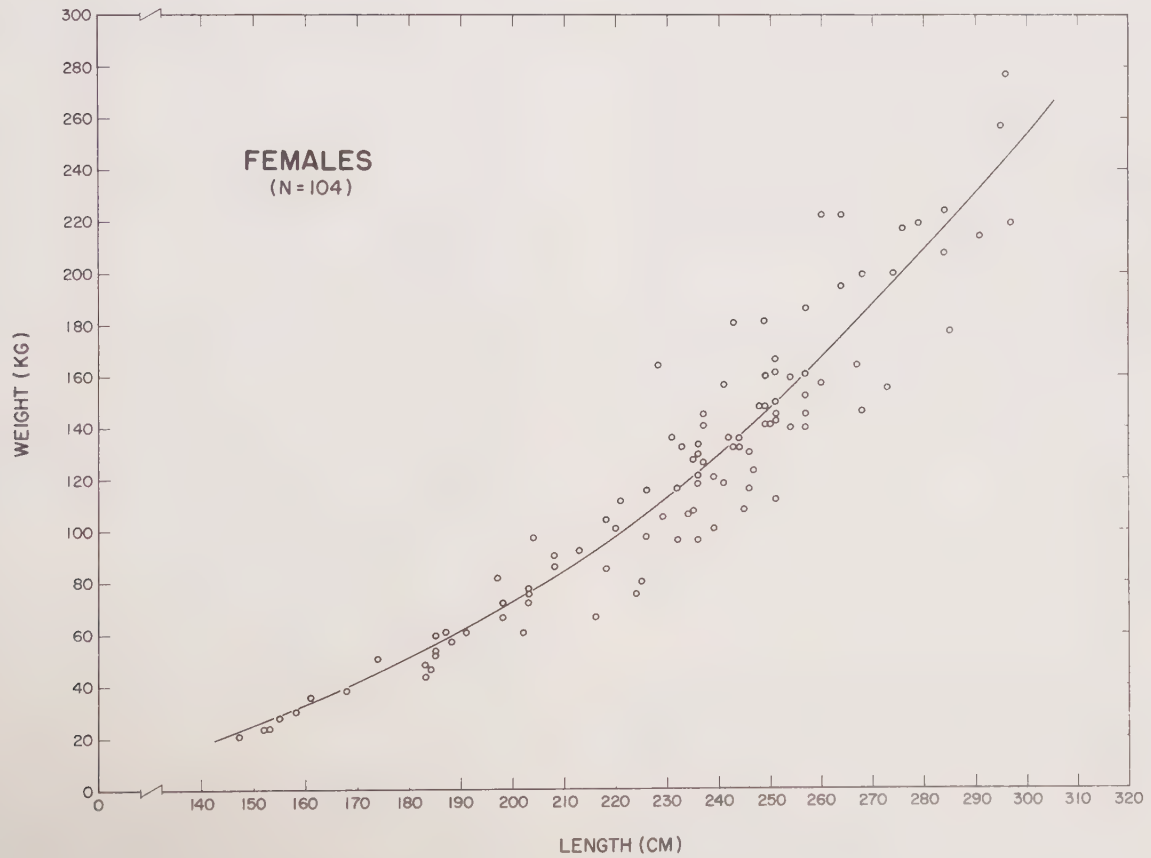

Figure 2.—The length-weight relationship of female blue marlin in the western Atlantic Ocean.

4.42 Factors causing or affecting mortality

No information available.

4.43 Factors affecting morbidity

No information available.

4.44 Relation of morbidity to mortality rates

No information available.

4.5 Dynamics of Population (as a Whole)

There is not enough information to permit construction of mathematical models for prediction of catch characteristics.

4.6 The population in the Community and the Ecosystem

The species composition of the community is that of the pelagic tropical and subtropical habitat. Several species of billfishes and tunas are sympatric and syntopic with the blue marlin and probably compete with it for food and space. Among those attaining a size comparable to that of young and adult blue marlin are the black marlin;, striped marlin; white marlin; longbill spearfish, *Tetrapturus pfluegeri*; shortbill spearfish, *T. angustirostris*; sailfish; bluefin tuna, *Thunnus thynnus*; bigeye tuna, *T. obesus*; and yellowfin tuna, *T. albacares*. In the Atlantic, the blue marlin occurs with white marlin, longbill spearfish, sailfish, bluefin tuna, bigeye tuna, and yellowfin tuna. In the Pacific and Indian oceans, the blue marlin occurs with black marlin, striped marlin, shortbill spearfish, sailfish, bluefin tuna, bigeye tuna, and yellowfin tuna.

Because the blue marlin is a large predator it is considered a climax feeder after reaching the adult stage.

See 2.22 and 3.32 for information on physical features of the biotope and changes in environmental factors.

5 EXPLOITATION

5.1 Fishing Equipment

5.11 Gear

In the commercial fishery the gear in current use is the conventional Japanese longline which is described amply in the literature (Nakamura, 1938; Bullis 1955; Captiva 1955). Off Havana, Cuba blue marlin are taken commercially with palangres, a type of gear similar to the longline but with only a few hooks.

In the sport fishery, blue marlin are taken by conventional rod and reel methods. Natural or artificial baits are trolled at the surface at speeds varying from 4 to 8 knots. Usually two to four lines are fished simultaneously. Echo sounders or fish detectors are not used, but bathythermographs are used to locate the depth of the thermocline. Longline gear is usually fished above the thermocline.

In the sport fishery, artificial hookless wobbling lines called "teasers" are trolled close behind the boat. Presumably, the action of these teasers attracts marlin to the bait. It is also the opinion of many anglers and fishing guides that the size of the boat and degree of vibration of the motors are instrumental in attracting the marlin. Nakamura and Rivas (1972) analyzed the effect of boat size in the northern Gulf of Mexico but could not reach any definite conclusions.

5.12 Boats

Japanese-type longliners are used in the commercial fishery with certain modifications in size and equipment according to locality. The Cuban palangre referred to above is tended from small boats powered by sail and/or motors (inboard or outboard).

5.2 Fishing Areas

5.21 General geographical distribution

The geographic distribution of commercial fishing areas corresponds to the geographic distribution of the species as discussed in 2.1. Sport fishing areas are limited to only a few countries.

In the United States, sportsmen fish for blue marlin off southern Texas, Louisiana, Alabama, northwestern and southeastern Florida, North Carolina, southern California, and Hawaii. Active sport fishing is also conducted off Puerto Rico and the Virgin Islands.

In the Bahama Islands, an active sport fishery for blue marlin is conducted off Bimini, Cat Cay, Cay Sal, Grand Bahama, and Walkers Cay. Many blue marlin are caught in the Tongue of the Ocean off the east coast of Andros, the largest island of the group.

In Mexico, most of the blue marlin sport fishery occurs along the Pacific coast. Acapulco, Mazatlán, and the southern tip of Baja California are the most active areas; however, blue marlin are not caught in large numbers in these areas.

In Central and South America most of the sport fishing for blue marlin takes place along the Pacific coast. There is an active sport fishery off Piñas Bay, Panama and another off Ecuador. Sport fishing for blue marlin in Venezuela is conducted mostly off La Guaira.

In the central Pacific, blue marlin are commonly taken around the Hawaiian Islands and Tahiti.

In Africa, blue marlin have been caught by sportsmen off Senegal and the Ivory Coast. A more active sport fishery, however, is conducted along the coast of South Africa.

In the Indian Ocean, blue marlin are taken by

anglers fishing off Mauritius. Cairns, on the east coast of Australia, is rapidly becoming a very active sport fishing center for blue marlin as well as other species of marlin. An active sport fishery for blue marlin has existed off northern New Zealand for several years.

5.22 Geographic ranges

According to data published by Howard and Ueyanagi (1965) and Ueyanagi et al. (1970) the commercial longline fishery for blue marlin takes place in the high seas as well as near the coast. The distance from the coast of commercial operations is limited by oceanographic conditions (temperature, depth, etc.) affecting the occurrence of the fish or by restrictions imposed by the various countries. In the sport fishery, the range of the fishery is limited by the range of the boats used by the anglers as well as oceanographic conditions. For example, off Bimini the habitat favorable to the blue marlin is found only 3 or 4 miles from shore. Off Louisiana and northwest Florida, however, blue marlin are usually found not less than 40 miles from shore.

The areas of greatest abundance have already been discussed in 2.1 and 2.3.

Commercial longline fishing for blue marlin in the Atlantic Ocean developed rapidly from 1958 to 1962 (Ueyanagi et al., 1970). After that year commercial fishing operations covered practically the entire distributional area of the blue marlin in the Atlantic.

The sport fishery for blue marlin has grown steadily since its inception early in this century; growth has been particularly rapid since the end of World War II. Some of the sport fishing areas developed as a result of commercial or exploratory fishing operations. Off South Pass, La., the sport fishery for marlins and tunas started in the midfifties following longline exploratory work by the Bureau of Commercial Fisheries (now National Marine Fisheries Service) (Bullis, 1955; Captiva, 1955).

5.23 Depth ranges

No information available.

5.24 Conditions of the grounds

No information available.

5.3 Fishing Seasons

5.31 General pattern of seasons

The fishing seasons vary according to the seasonal movements of the fish as discussed in 2.1 and 3.51.

5.32 Dates of beginning, peak, and end of season

In the commercial fishery the longline fleets can follow the seasonal movements of the fish; however, this is not true for the sport fishery. For example, in the northern Gulf of Mexico the sport fishing season begins in April or May, reaches a peak in July and August, and ends in October or November (Nakamura and Rivas, 1972). On the other hand, in tropical areas such as Puerto Rico and Jamaica, sport fishing for the blue marlin is conducted throughout the year.

5.33 Variation in date or duration of season

As discussed above in 5.32, the off-season for the sport fishery in the northern Gulf of Mexico is from November to April. During that period adverse weather conditions prevent sport fishing boats from venturing out. Furthermore, low water temperatures render the habitat unsuitable to the blue marlin. The same applies to the sport fishery in areas with a similar climate.

5.4 Fishing Operations and Results

5.41 Effort and intensity

In the longline fishery the unit of effort is the number-of-fish-per-hundred-hooks. In the sport fishery the same unit of effort may be used, but Nakamura and Rivas (1972) have suggested that number-of-fish-raised-per-hour-of-trolling may be a better index of relative abundance.

Ueyanagi et al. (1970) have given the monthly change of the mean hook-rate by area for the blue marlin in the Atlantic Ocean during 1956 through 1965.

In the commercial longline fishery the causes of variation in fishing effort are the result of changes in economic factors and fluctuations in stock abundance. In the sport fishery, weekends, national holidays, and traditional summer vacations are causes of variation in fishing intensity. In general, fishing intensity is highest on weekends. In certain areas, such as the northern Gulf of Mexico, sport fishing intensity drops markedly during the Labor Day weekend. Presumably, anglers select that particular holiday to spend time with their families before the children go back to school. However, in areas such as southern California this is the period when the peak fishing effort for billfish occurs.

5.42 Selectivity

The longline is selective for larger fish and in the sport fishery the baits are rigged to catch the larger fish. Anglers and fishing guides believe that the larger the bait and the hook, within limits, the larger the blue marlin that the bait will attract. This is the rule only in certain areas. Off South Pass, La., anglers troll mostly large baits with a corresponding large hook. They specialize almost exclusively in blue marlin fishing and usually catch more of them (number-of-fish-per-hour-of-trolling) as compared to northwest

Florida where smaller baits are trolled (Nakamura and Rivas, 1972). At present there is no way of telling whether the better catches off South Pass result from larger baits, better fishermen, or greater abundance of blue marlin.

5.43 Catches

Ueyanagi et al. (1970) have given the annual longline catches (1958-66) of blue marlin for the Atlantic Ocean on the basis of numbers of fish caught rather than total weights. Their graph shows the estimated catches of blue marlin by year is as follows:

Year	*Estimated catch (number)*
1958	8,900
1959	21,500
1960	26,100
1961	41,200
1962	110,400
1963	95,300
1964	82,900
1965	44,000
1966	20,200

Annual longline catches (1962-70) of blue marlin were recently published by Gottschalk (1972) for the entire Atlantic and the eastern Pacific. In the Atlantic, the catches are expressed in the number of fish caught:

Year	*Fish caught (number)*
1962	111,000
1963	96,000
1964	84,000
1965	45,000
1966	22,000
1967	11,000
1968	9,000
1969	14,000
1970	11,000

In the eastern Pacific, there were:

Year	*Fish caught (number)*
1962	37,000
1963	76,000
1964	46,000
1965	26,000
1966	22,000
1967	22,000
1968	28,000
1969	34,000
1970	20,000

Data collected from the sport fishery of the northern Gulf of Mexico during the 1971 season (May to October) show that 84 blue marlin weighing a total of 8,995 kg (19,788 lb) were caught. Of these, 20 were, males weighing 28 to 127 kg (62 to 280 lb) and 64 were females weighing 21 to 224 kg (46 to 492 lb). Average weight of males was 71 kg (156 lb) and that of females was 118 kg (260 lb). The average weight of all 84 fish, males and females combined, was 107 kg (236 lb). The fish were caught out of South Pass, La., and Pensacola, Destin, and Panama City, Fla.

6 PROTECTION AND MANAGEMENT

6.1 Regulatory (Legislative) Measures

6.11 Limitation or reduction of total catch

At present, there are no limitations or reductions of any kind applying to the blue marlin fishery. A steady decline in the catch, however, since 1962 (see 5.43 above) has called attention to the need for regulatory measures. Analysis of the annual catches of blue marlin in the Atlantic from 1958 to 1962 shows the pattern of a virgin fishery when first opened to exploitation. Instead of leveling off, however, the catch has steadily declined since 1962, despite increased effort, from 111,000 fish to 11,000 in 1970. I have no information on whether or not the average size of the blue marlin has also declined.

6.12 Protection of portions of population

There are no closed areas or seasons and there are no limitations on gear. There are, however, limitations on the use of blue marlin for food in the United States according to the degree of mercury contamination of the flesh. Shomura and Craig (1974) reported on the total mercury levels found in the white muscle tissue of 37 blue marlin caught in Hawaiian waters. Thirty of the 37 fish had mercury levels that exceeded the 0.5 ppm. level used as a guideline by the U.S. Food and Drug Adminstration as fit for human consumption. The mercury levels ranged from 0.7 to 7.86 ppm. in fish weighing between 43.5 and 410.9 kg (96 and 906 lb, respectively).

7 POND FISH CULTURE

Not applicable.

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Synopsis of the Biology of the Black Marlin, *Makaira indica* (Cuvier), 1831

IZUMI NAKAMURA[1]

1. IDENTITY

1.1 Nomenclature

1.11 Valid name

Makaira indica (Cuvier) 1831.

Original combination: *Tetrapturus indicus* Cuvier 1831. *In* Cuvier and Valenciennes, Hist. Nat. Poiss. Paris 8:286-287. (Original locality: Sumatra.)

1.12 Objective synonymy

Tetrapturus indicus Cuvier 1831. *In* Cuvier and Valenciennes, Hist. Nat. Poiss. Paris. 8:286-287.
Makaira indica Jordan and Evermann 1926. Calif. Acad. Sci., Occas. Pap. 12:67.
Makaira indicus (partim) Deraniyagala 1933. Spolia Zeylan. 18:55-56.
Istiompax indicus Morrow 1959. Copeia 1959:347-349.
Makaira (Istiompax) indica Robins and de Sylva 1960. Bull. Mar. Sci. Gulf Caribb. 10:406.

1.2 Taxonomy

1.21 Affinities

Suprageneric

Phylum Chordata
Subphylum Vertebrata
Superclass Gnathostomata
Class Osteichthyes
Subclass Actinopterygii
Order Perciformes
Suborder Xiphioidei
Family Istiophoridae

Generic

Genus *Makaira* Lacépède.

Makaira Lacépède 1803, Hist. Nat. Poiss. 4:688. (Type-species: *Makaira nigricans* Lacépède 1803.)

This genus is distinguished by the height of first dorsal fin being less than body depth, short pelvic fin with poorly developed membrane, body slightly compressed laterally, posterodorsal part of the head remarkably convex, skull stout and broad, neural and haemal spines showing a high trapezoid when viewed laterally, lateral apophysis of vertebrae well developed, vertebral count of 11 + 13 = 24 (Nakamura, Iwai, and Matsubara, 1968).

Specific

Types of this species might be unknown. This species was described from a drawing of a specimen 274 cm (9 feet) long and weighing 440 kg (200 pounds), from Sumatra.

The substance of the original description of this species is as follows:

> Spear long, five times in body length including caudal fin, dorsal lobe 1⅓ to 1 in depth of body, ventrals one-half of depth; dorsal fin low posteriorly, the 4th or 5th middle spines highest and nearly equal to body depth.

This species is distinguished clearly from other members of *Makaira* by its rigid pectoral fin and a second dorsal fin situated a little forward of the insertion of the second anal fin (Nakamura et al., 1968).

Subjective synonymy

Tetrapturus australis Macleay 1854. Illus. Sydney News 1(23):179.
Histiophorus brevirostris Playfair 1866. *In* Playfair and Günther, The fishes of Zanzibar, p. 53 and 145, London.
Histiophorus gladius Ramsay 1881 (*non* Bloch 1793). Proc. Linn. Soc. N.S.W. 5:295-297.
Makaira marlina Jordan and Hill 1926. *In* Jordan and Evermann. Calif. Acad. Sci., Occas. Pap. 12:59-60, pl. 17.
Istiompax australis Whitley 1931. Rec. Aust. Mus. 18(4):147-150.
Makaira nigricans tahitiensis Nichols and LaMonte 1935. Am. Mus. Novit. 807:1-2.
Makaira nigricans marlina Nichols and LaMonte 1935. Nat. Hist., N.Y. 36:328.
Makaira ampla marlina Nichols and LaMonte 1941. Ichthyol. Contrib. Int. Game Fish Assoc. 1(1):8, fig. 1.

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Makaira ampla tahitiensis Nichols and LaMonte 1941. Ichthyol. Contrib. Int. Game Fish Assoc. 1(1):8, fig. 3.
Tetrapturus brevirostris Smith 1946. Ann. Mag. Nat. Hist. 11:793-807.
Marlina marlina Hirasaka and Nakamura 1947. Bull. Oceanogr. Inst. Taiwan 3:15, pl. 3, fig. 1.
Istiompax dombraini Whitley 1954. Aust. Zool. 12 (1):60.
Makaira mazara (partim) LaMonte 1955 (*non* Jordan and Snyder 1901). Bull. Am. Mus. Nat. Hist. 107: 336.
Makaira mazara tahitiensis LaMonte 1955. Bull. Am. Mus. Nat. Hist. 107:342.
Makaira xantholineata Deraniyagala 1956. Spolia Zeylan. 28(1):23-24.
Istiompax marlina Royce 1957. U.S. Fish Wildl. Serv., Fish. Bull. 57:524-528, fig. 2d, 3a.
Istiompax brevirostris Morrow 1958. Bull. Mar. Sci. Gulf Caribb. 8:358.
Makaira australis Marshall 1964. Fishes of the Great Barrier Reef and coastal waters of Queensland, p. 349-350, pl. 47, Narberth.

The following key to the species of *Makaira* is based on Nakamura et al. (1968):

a. Pectoral fin folds back against the side of the body. Lateral line not single line.
b. Lateral line system simple loops in shape - - - - *Makaira mazara* Jordan and Snyder, Indo-Pacific blue marlin.
bb. Lateral line system reticulate - - - - *Makaira nigricans* Lacépède, Atlantic blue marlin.
aa. Pectoral fin extends stiffly away from the body, cannot be folded back against the side of the body. Lateral line obscure but single line - - - - *Makaira indica* (Cuvier), black marlin, (Fig. 1).

1.22 Taxonomic status

This species was placed in genus *Istiompax* by several authors, e.g., Whitley, 1931a, 1931b, 1948, 1955; Royce, 1957; Morrow, 1959a, 1959b, 1959c, but many other authors have placed it in genus *Makaira*. Species concept of *M. indica* is still one of a morphospecies.

1.23 Subspecies

Some authors proposed a subspecies status for this species, e.g., Nichols and LaMonte, 1935a, 1935b; LaMonte and Marcy, 1941; Rosa, 1950; Morrow, 1954, 1957, but this has not been generally accepted due to the lack of adequate evidence. Further studies on geographical morphological forms or subspecies are highly needed.

1.24 Standard common names and vernacular names

In current scientific literature "black marlin" is invariably used as the common name for *Makaira indica.*[2] The following vernacular names are used by fishermen:

Location	*Common name*
Sri Lanka (general)	Marlin, Ahin Koppara
Sri Lanka (Tamil)	Kopparan, Kopparaikulla
Sri Lanka (Sinhala)	Kapparava, Makara, Sapparava
Indonesia	Joo Hoo
U.S.A.	Pacific black marlin, giant black marlin, silver marlin
New Zealand, Australia, New Guinea	Black marlin
Formosa	Kŷau-shit-á
Tokyo, Japan	Shirokawa
Kochi, Japan	Genba
Okinawa, Japan	Shiruachi
Various parts of Japan	Shirokajiki, Shirokawakajiki

[2]"Black marlin" as the common name for *Makaira indica* was not universally accepted until the mid-1960's. Prior to this agreement, some authors, principally scientists from Japan, called this species "white marlin" (see for example Ueyanagi, 1964). To add to this confusion, much of the earlier Japanese literature used "black marlin" to refer to the species currently known as "blue marlin," *Makaira nigricans.* The fact that the scientific names have gone through a similar period of changes has not helped the nomenclature situation any.

Figure 1.—Black marlin, *Makaira indica* (Cuvier).

1.3 Morphology

1.31 External and internal morphology

Description of adult (after Nakamura et al. 1968):

First dorsal fin rays 38-42, second dorsal fin rays 6-7, first anal fin rays 13-14, second dorsal fin rays 6-7, pectoral fin rays 19-20, pelvic fin 1, 2.

Body elongated (greatest depth of body[3] about 4.8-5.2 in body length), slightly compressed laterally (width of body at origin of pectorals about 11.0-13.4 in body length). Snout long (bill length about 0.95 in head length) with a cross section nearly circular. Scales distributed densely on body surface; scale ends pointed and long.

Rasplike teeth on jaws and palatine. Lateral line obscure but consists of a single line. Head large (head length about 4.0-4.2 in body length). Eye moderate in size. Posterodorsal part of the head between preorbital and origin of the first dorsal fin strongly convex. Caudal fin large and strongly falcate. A pair of keels situated a little posteriorly on caudal peduncle. Pectoral fin situated low on body, long (length of pectoral fin about 1.1-1.3 in head) and its tip pointed. Pectoral fin extends stiffly away from the body, cannot be folded back against the side of the body. First dorsal fin starts above supraposterior margin of the opercle and ends just before the origin of the second dorsal fin; anterior portion lower than the body height and gradually decreasing in height posteriorly. The tip of the anterior part of the first dorsal fin pointed. First anal fin large and triangular in shape, its tip pointed. Second dorsal fin nearly equal to second anal fin in size and shape, origin opposite each other, or the former a little farther forward than the latter. Pelvic fin shorter than pectoral fin.

Membrane of first dorsal fin dark blue, other fin membranes brownish black. No marks or blotches on the body. Dorsal part of the body blackish dark blue, ventral part of body silvery white. Color of the body fades after death, so this species is called "Shirokajiki" (= white marlin) in Japan. While alive, the color of body is tinged with black, and hence this species is called "black marlin" in English-speaking countries.

Nasal rosette composed of about 50 laminae. Gonad symmetrical. Anus situated just anterior of the origin of first anal fin. Skull broad and strong; the preorbital part elongated and its postorbital part shortened. Ventral part of the vomer and anteroventral part of the parasphenoid flat. Temporal ridge parallel with pterotic ridge. Haemal and neural spines of the central part of vertebrae high trapezoid in shape. Lateral apophysis well developed but not so much as in *Makaira mazara* and *M. nigricans*. Vertebrae 11 + 13 = 24.

[3]Measurements were carried out by the method of Rivas (1956).

2. DISTRIBUTION

2.1 Total Area

Black marlin are distributed widely in the Indian and Pacific oceans; very few catches have been recorded from the Atlantic Ocean (Fig. 2). Only stray black marlin seem to invade the Atlantic Ocean by way of the Cape of Good Hope; possibly breeding stocks do not exist in the Atlantic Ocean. Good commercial fishing grounds exist in the East China Sea, around Formosa, in the waters off northwest Australia, the Arafura Sea, the Sulu Sea, the Celebes Sea, and the Coral Sea. Good sport fishing grounds for black marlin are found in Piñas Bay of Panama and off Ecuador (Fig. 3).

Sea surface temperatures at or near the areas where the black marlin are caught range from about 15° to 30°C (Howard and Ueyanagi, 1965).

2.2 Differential Distribution

2.21 Spawn, larvae, and juveniles

Very few larvae have been obtained from the tropical western north Pacific, tropical Indian Ocean, and tropical water off northwestern Australia and the Coral Sea (Ueyanagi, 1964). It has been surmised that the spawning grounds are in the northwestern part of the Coral Sea (Ueyanagi, 1960; Ueyanagi and Yabe, 1960) and in the vicinity of Hainan Island, South China Sea (Nakamura, 1941, 1942). But spawn is not identified.

2.22 Adults

This species is distributed widely in warmer parts of the Pacific Ocean and the Indian Ocean and densely in coastal waters. In tropical open seas areas, distribution is very scattered but continuous, whereas in temperate open seas, there is almost no occurrence of this species (Howard and Ueyanagi, 1965). In tropical open seas areas, there is a tendency for this species to occur in the vicinity of islands (Nakamura, 1953; Royce, 1957; Koto, Furukawa, and Kodama, 1959; Ueyanagi, 1963).

2.3 Determinants of Distribution Changes

In the East China Sea, black marlin fishing grounds, which are shallower than those of the other billfishes, are found in the areas where the Kuroshio and Tsushima currents are mixed with the waters of the Yellow Sea (Koto et al., 1959). Optimum temperatures for harpoon fishing of black marlin westward of Uotsurijima in the East China Sea, are 23° to 25°C between October and April (Morita, 1952).

2.4 Hybridization

No data.

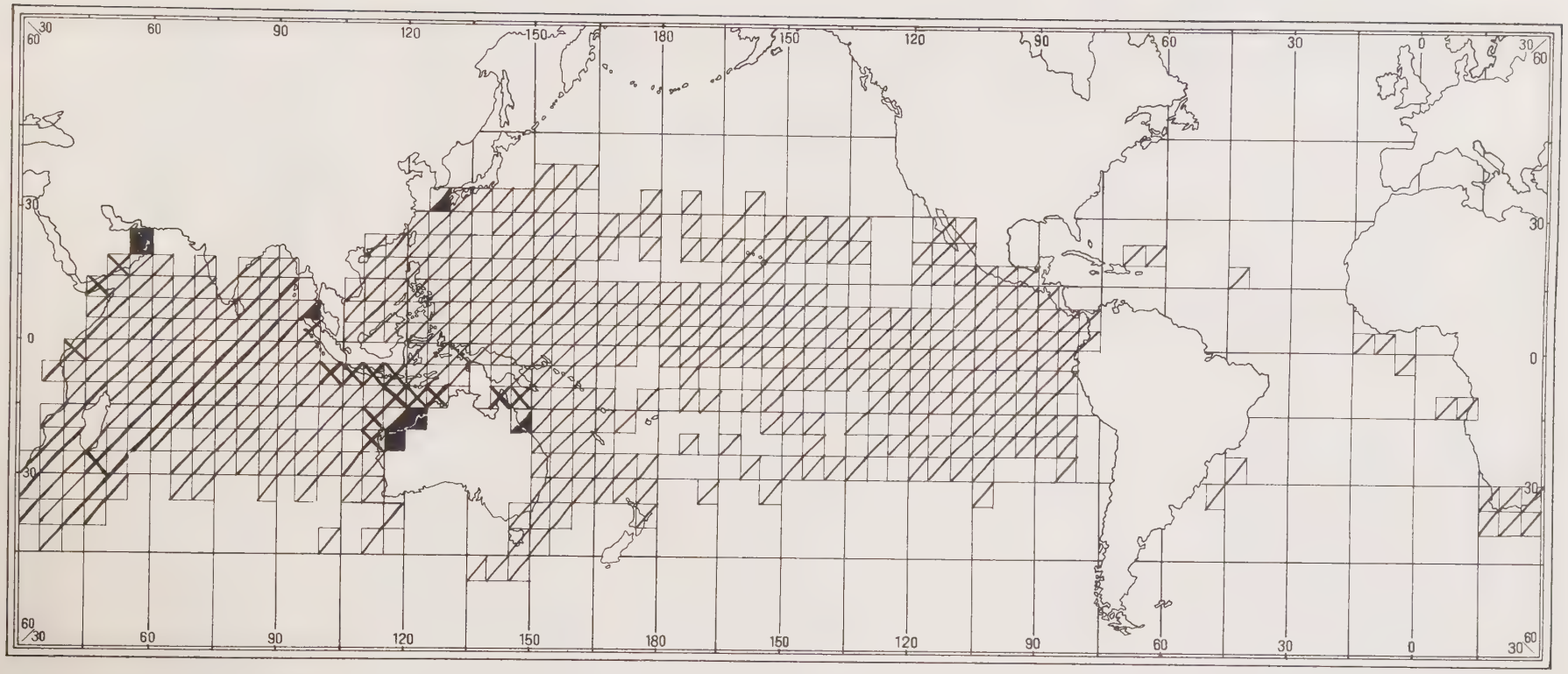

Figure 2.—Distribution and relative abundance of black marlin based on the data from the Japanese longline fisheries in 1969 (chiefly), 1968, 1967, and 1964.

3. BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

The sexes of the black marlin are separate. The males and females cannot be distinguished by external characters. In the waters around Formosa, the sex ratio is 53/414 male throughout a size range of 20 to 200 kg in body weight (Nakamura, 1944a). Females become larger than males (Nakamura, 1944b).

3.12 Maturity

Age at which sexual maturity is reached is not known.

3.13 Mating

The mating of the black marlin has not been observed.

3.14 Fertilization

External.

3.15 Gonad

Black marlin are densely distributed in the northwestern part of the Coral Sea between October and December. Almost all fishes caught in this area have well-developed gonads (Table 1); thus these fishes are believed to be from spawning schools in this area. The skewed sex ratios may also be indicative of this possibility (Ueyanagi, 1960).

Merrett (1970) studied histological gonad development in billfishes including this species from the Indian Ocean.

3.16 Spawning

There is very little information relating to spawning grounds and spawning seasons of the black marlin. Nakamura (1941, 1942, 1944b) surmised that spawning occurs in the vicinity of Hainan Island and the South China Sea in May or June. Ueyanagi (1960) also presumed spawning to occur in the northwestern part of the Coral Sea between October and December.

The sex ratio of the black marlin varies with area and season (Table 2). Variations in sex ratios seem to be related to spawning (Nakamura, 1942).

3.17 Spawn

The egg of the black marlin seems to be pelagic and nonadhesive, but details are not known.

3.2 Preadult Phase

3.21 Embryonic phase

No data.

3.22 Larvae phase

The embryological development of the black marlin is not known. Some larvae have been obtained by research vessels. Morphological features of these larvae have been described by Ueyanagi (1964).

The back of the larvae is slightly concave where the

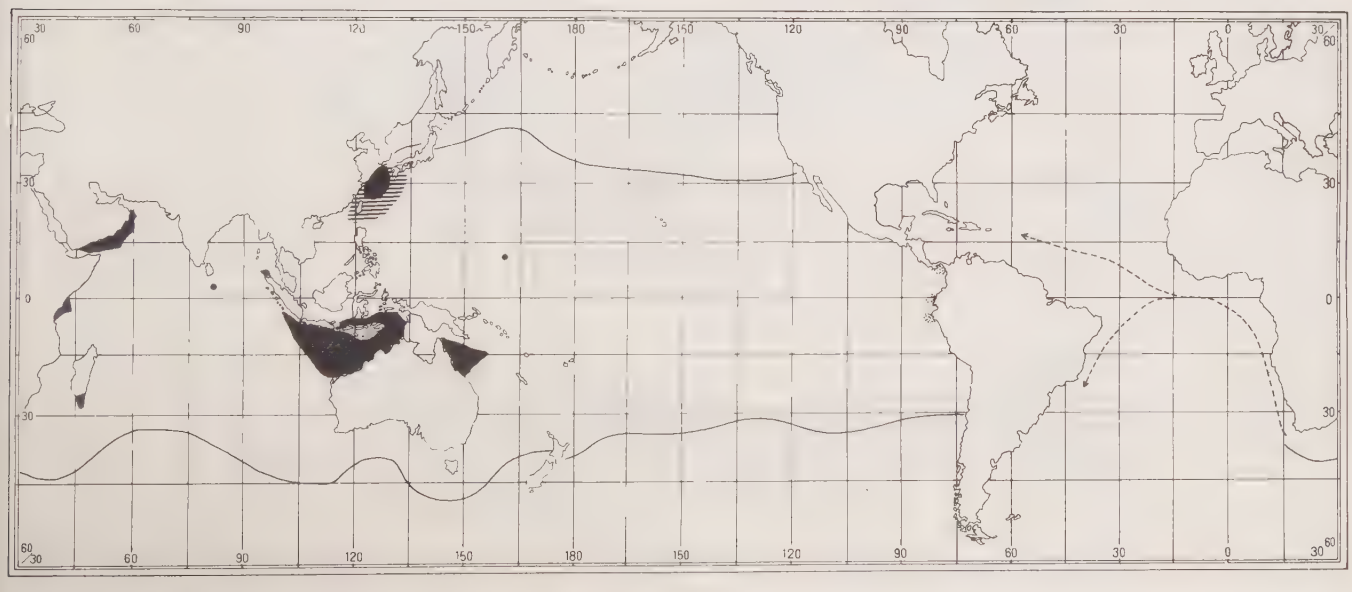

Figure 3.—Distribution and fisheries of black marlin. Shaded areas show good fishing grounds for commercial longline fisheries. Horizontal barred area shows harpoon fishing ground. Dotted areas show sport fishing grounds. Solid line indicates northern and southern limits of distribution of black marlin based on data from the longline catches. Dotted line shows movement of black marlin from the Indian Ocean into the Atlantic Ocean.

Table 1.—Data on the gonad weight of *Marlina marlina* (Jordan and Hill) in the northwestern area of the Coral Sea during November 1956 (*No. 1 Satsuma-maru*) (Ueyanagi, 1960).

Body length (cm)	Testis weight (g)					Ovary weight (g)					
	less than 500	500-1,000	1,000-2,000	2,000-4,000	more than 4,000	less than 500	500-1,000	1,000-2,000	2,000-5,000	5,000-10,000	more than 10,000
131-140	1			1							
141-160	5	18	25								
161-180	2	38	84	22					1		
181-200		11	66	58	6						
201-220	1	4	13	95	30					2	
221-240				24	31				2	5	
241-260				2	3				1	12	9
261-280				1					1	7	11
281-300									3	2	8
301-320										3	7

head joins the trunk. This species can be identified also by the short snout, specific shape of the pectoral fin and vertebral formulae (11 + 13). Because of similar short snouts, the head profile of the black marlin larvae resembles that of blue marlin; however, the two species can be discriminated since the blue marlin has eye orbits with protruding anterior edges. In small specimens under 6 mm the snout is also somewhat longer than in the blue marlin. The shape of the pectoral fin is unique in larvae over 3.5 mm. In specimens 3.5 mm in length, the pectoral fin stands out rigidly from the lateral side of the body and cannot be folded against the body without breaking the joint. In specimens of about 5 mm not only does this characteristic become more distinct, but also the fin is turned slightly counterclockwise, because of the distortion of the base of the fin. Even in specimens of 23 mm in length, the transition of the fin to the adult condition is not yet complete, but it has progressed far enough to show a relationship with the adult form. In addition, the shape of the dorsal fin seems to be different in this species (Fig. 4).

Table 2.—The sex ratio of the black marlin in various areas.

Date	Localities	Female		Male		References
		No.	%	No.	%	
Dec. 1937	Suao	44	85	8	15	Nakamura, 1942
July 1939	Hainan Island	4	25	12	75	Nakamura, 1942
Dec. 1939	Suao	44	92	5	8	Nakamura, 1941
Mar. 1940	Kaohsiung	52	87	8	13	Nakamura, 1942
Nov. 1940	Suao	8	80	2	20	Nakamura, 1942
Jan. 1941	Suao	16	89	2	11	Nakamura, 1942
May 1941	Kaohsiung	11	71	3	29	Nakamura, 1942
Jan. 1942	Suao	15	94	1	6	Koto and Kodama, 1962
Nov. 1942	Suao	22	85	4	15	Koto and Kodama, 1962
Nov. 1942	Kaohsiung	22	82	5	18	Koto and Kodama, 1962
Dec. 1942	Suao	60	82	14	18	Koto and Kodama, 1962
Jan. 1943	Suao	18	75	6	25	Koto and Kodama, 1962
Feb. 1943	Kaohsiung	16	94	1	6	Koto and Kodama, 1962
Mar. 1943	Kaohsiung	9	90	1	10	Koto and Kodama, 1962
Apr. 1943	Kaohsiung	16	94	1	6	Koto and Kodama, 1962
May 1943	Kaohsiung	15	100	0	0	Koto and Kodama, 1962
Dec. 1943	Suao	78	86	13	14	Koto and Kodama, 1962
Feb. 1944	Suao	83	85	15	15	Koto and Kodama, 1962
Feb. 1944	Kaohsiung	24	89	3	11	Koto and Kodama, 1962
Mar. 1944	Kaohsiung	32	100	0	0	Koto and Kodama, 1962
1942-1944	Kaohsiung	107	95	6	5	Nakamura, 1944a
1942-1944	Suao	254	84	47	16	Nakamura, 1944a
Nov. 1956	Northwestern area of the Coral Sea	541	88	74	12	Ueyanagi, 1960
1952-1956	Eastern Sea of Formosa	361	88	51	12	Koto and Kodama, 1962
Sep. 1964-Dec. 1967	Equatorial western Indian Ocean	7	88	1	12	Merrett, 1971

3.23 Adolescent phase

No data on the stages between 23 and ca. 1,300 mm in body length.

3.3 Adult Phase

3.31 Longevity

No data.

3.32 Hardiness

No data.

3.33 Competitors

Generally, large sharks are thought to be competitors or predators and tunas and small marlins are thought to be competitors or victims for large marlins (*Makaira* spp.) and swordfish (Parin, 1968).

3.34 Predators

Pelagic carnivorous fishes such as sharks, scombroids, carangoids, and other istiophorids are predators of larval and juvenile stages of the black marlin. There are no true predators on the adult fish.

3.35 Parasites, diseases, injuries, and abnormality.

No data except parasites on which some descriptions are in the papers of Silas (1967) and Silas and Ummerkutty (1967).

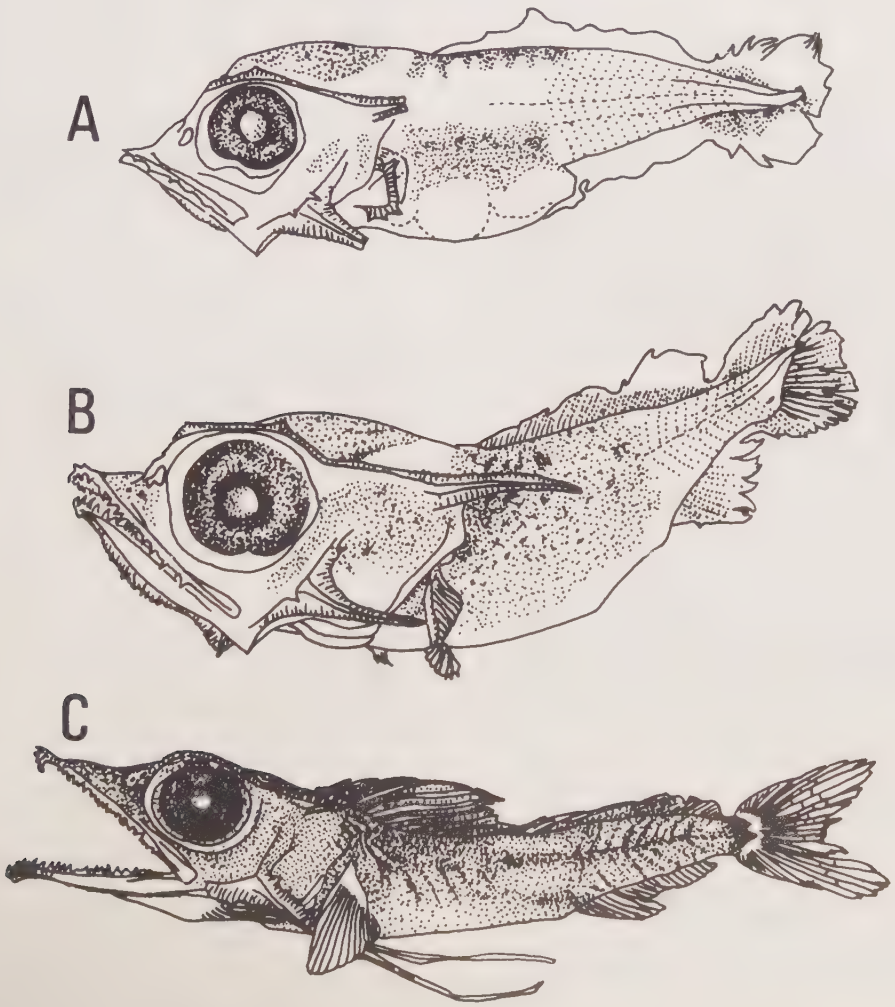

Figure 4.—Larvae of the black marlin. A. 3.6 mm in body length. B. Approximately 5.2 mm in body length. C. 23 mm in body length. (From Ueyanagi, 1960.)

3.4 Nutrition and Growth

3.41 Feeding

Very little is known about the feeding behavior of the black marlin. During fishing operations off Hana, Maui, a large black marlin (referred to as silver marlin in the publication; see footnote 2) was caught on a longline at a depth of about 60 fathoms. The fish had an abnormally distended abdomen and, upon gutting, a bigeye tuna, *Thunnus obesus* Lowe, was found in the stomach. This tuna, which weighed about 160 pounds (72.7 kg), had been caught on the longline first, for the hook was still set in the tuna's mouth when the specimen was removed from the stomach of the marlin. The marlin evidently had found the hooked tuna an easy prey and swallowed it head first (June 1951). Black marlin have often been observed to swallow adult skipjack tuna, *Euthynnus pelamis* (Linnaeus), or bigeye tuna, head first (Togo, pers. commun.[4]).

3.42 Food

Tanoue (1953) studied the food of the black marlin near Mangole Island and Timor Island. The most important food items of the black marlin from Mangole Island were various fishes such as *Decapterus, Auxis, Gempylus serpens* Cuvier, *Pseudoscopelus,* Tetraodontidae, Atherinidae, and Paralepididae and decapod molluscs. Principal food items of black marlin from Timor Island were fishes such as Syngnathidae, *Auxis* and *Oxyporhamphus,* and megalop larvae of Crustacea, Isopoda, and decapod molluscs.

In the East China Sea, most important food items of black marlin are mackerels, *Scomber* spp. and horse mackerels, *Trachurus* spp. (Morita, 1960).

Watanabe (1960) studied the food of the black marlin in the Pacific equatorial waters. Fishes of the families Scombridae, Gempylidae, Coryphaenidae, Xiphiidae, and Carangidae and decapod molluscs were the most important food of the black marlin. Fishes of the families Sternoptychidae, Paralepididae, Alepisauridae, Chiasmodontidae, Chaetodontidae, Balistidae, Ostraciontidae, and Tetraodontidae, and octopods and macrura crustaceans were of lesser importance.

3.43 Growth Rate

Koto and Kodama (1962) studied the black marlin of the East China Sea, and the annual growth in length was estimated as follows: 1) in the 150- to 200-mm group (the minimum size class in the commercial catches) the annual growth is 50 cm; 2) in the 200- to 230-cm group, which is 1 yr older than the above group, it is 30 cm; 3) in the 230- to 250-cm group, it is 20 cm; and 4) above the 250-cm group, it is difficult to estimate the annual growth, as seasonal shifts of the modes are not discernible. Black marlin in the East China Sea grow most rapidly during the period from early summer to late autumn.

3.44 Metabolism

No studies.

3.5 Behavior

3.51 Migration and local movement

In the East China Sea, the schools of the black marlin migrate northward during spring and summer and migrate southward during autumn and winter (Koto et al., 1959). In the Japan Sea some black marlin seem to migrate northward with the core of the Tsushima Current during summer and migrate southward against the Tsushima Current during late summer and early autumn (Nakamura, unpubl. data).

In the tropical western Indian Ocean, the black marlin is more abundant during the northeast monsoon period than the southeast monsoon (Merrett, 1971).

3.52 Schooling

There is little data on the schooling behavior of the black marlin. When the monsoonal winds change suddenly in direction and intensity around the waters of Taiwan, schools of black marlin appear at the surface. The harpoon fishery becomes active in this period (Nakamura, 1938).

3.53 Responses to stimuli

No data.

4. POPULATION

- 4.1 Structure
- 4.2 Abundance and Density of Population
- 4.3 Natality and Recruitment
- 4.4 Mortality and Morbidity
- 4.5 Dynamics of Population as a Whole
- 4.6 The Population in the Community and the Ecosystem

There are a few fragmentary observations on these topics under item 4, but there are no specific studies.

[4]Togo, S., 1972, personal communication on feeding habits of the black marlin. Soroku Togo is an expert technician on the research vessel of the Fisheries Agency of Japan.

5. EXPLOITATION

5.1 Fishing Equipment

5.11 Gears

Tuna longlines are employed to catch black marlin in most fishing grounds where this species occurs; areas include the East China Sea, the Sulu Sea, the Celebes Sea, and the Coral Sea. Harpoon fishing is carried out in the fishing grounds of Taiwan and southern Japan. Sport fishing using trolling gear catches many black marlin in Piñas Bay, Panama and off Ecuador.[5] Sometimes this species is caught by set net used to catch yellowtail in the Japan Sea.

5.12 Boats

The black marlin is mostly caught by ordinary tuna longliners. The vessels of the longline fleet vary considerably in size; the largest are about 1,900 tons with several small catcher boats stored on each side of the deck. Longline vessels are constructed of wood or steel; those of more than 100 gross tons are usually of steel. Most of the longliners are 250 to 350 gross tons; at this size they appear to be the most economical and efficient to operate (Yoshida, 1966).

Small wooden boats are employed for harpoon fishing in Taiwan and southern Japan. The wooden boat is about 10 m long, and is powered by a small engine.

Ordinary trolling motorboats are employed for trolling in the sport fisheries of Panama, northeastern Australia, and Ecuador. In these areas black marlin are caught more frequently than in other sport fishing grounds for tunas and billfishes.

5.2 Fishing Areas

5.21 General geographical distribution

The black marlin is distributed widely in the tropical and temperate waters of the Indo-Pacific, but more restricted in the Atlantic (Fig. 2). The species is taken commonly by tuna longline as a by-catch. The species is densely distributed in the vicinity of islands and in coastal waters. The most important commercial fishing grounds are in the East China Sea, the waters around Formosa, the waters around northwest Australia and the Coral Sea (Figs. 2, 3).

5.22 Geographical ranges

Spawning stocks of this fish are believed to be confined to the Indian and Pacific oceans. Specimens stray occasionally into the Atlantic Ocean (Fig. 2). From commercial fisheries data the northern limit is about lat. 40°N in the northern Pacific Ocean and about lat. 45°S in the southern Pacific Ocean and the Indian Ocean. In the southern area off Tasmania, the limit extends to lat. 50°S (Fig. 2).

5.23 Depth ranges

The commercial longline fishery is generally conducted in waters over 100 m deep. In the equatorial western Indian Ocean, peak catch rates of black marlin have been reported to occur at the 201- to 500-fathom depth range (Merrett, 1971). The swimming layer of this species is usually considered to be shallower than those of other species of billfishes.

5.24 Condition of the grounds

Most areas exploited at present are coastal water, but the grounds are various.

5.3 Fishing Seasons

In the East China Sea from lat. 30° to 34°N the fishing season begins in July and ends in January (peak in August, September, and October); from lat. 25° to 30°N the fishing season occurs from May to July and October to April with peaks in June and July, and October and January (Koto et al., 1959).

The fishing season begins in October and ends in April (peak in November and December) near Uotsurijima in the East China Sea (Morita, 1952). The fishing season around Formosa extends throughout the year; the peak occurs between October and December in the South China Sea, and in February and March off eastern Formosa (Nakamura, 1953).

5.4 Fishing Operations and Results

5.41 Effort and intensity

In all of the areas, there is insufficient data on effort and intensity of commercial fishing for this species. However, it is known that most of the effort and intensity occurs in the East China Sea, the waters around Formosa, the waters around northwest Australia, the Coral Sea, the Arafura Sea, the Sulu Sea, and the Celebes Sea.

5.42 Selectivity

No data.

5.43 Catches

Catches by Japanese tuna longliners for 1962 to 1970 are given in Table 3.

6. PROTECTION AND MANAGEMENT

6.1 Regulatory Measures

6.2 Control or Alteration of Physical Features of the Environment.

[5]Recently Cairns, Queensland of Australia has become famous for trolling of black marlin.

6.3 Control or Alteration of Chemical Features of the Environment

6.4 Control or Alteration of Biological Features of the Environment

6.5 Artificial Stocking

No data on above mentioned items.

7. POND FISH CULTURE

No data.

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Table 3.—Annual estimates by major fishing grounds, of fishing effort in numbers of hooks and catch in numbers of black marlin, 1962-70 (Anonymous, 1972).

Year	All major fishing grounds combined		Whole Pacific Ocean		North Pacific Ocean region		South Pacific Ocean region	
	Hooks (× 1,000)	Number of fishes (× 1,000)	Hooks	No.	Hooks	No.	Hooks	No.
1962	412,571	85	290,051	33	156,140	5	109,183	26
1963	449,427	62	337,113	32	154,036	4	130,976	23
1964	437,010	62	283,140	27	139,893	6	81,248	16
1965	466,204	69	288,771	38	152,942	12	92,226	23
1966	445,011	69	301,617	35	149,691	7	104,382	24
1967	463,461	58	305,999	22	192,960	6	70,615	12
1968	435,665	64	286,853	17	165,372	3	71,040	10
1969	436,815	58	306,024	22	168,750	5	70,114	13
1970	402,290	44	282,531	18	162,674	4	67,735	12

Year	Eastern Pacific Ocean region		Indian Ocean region		Atlantic Ocean region	
	Hooks	No.	Hooks	No.	Hooks	No.
1962	24,727	2	68,416	49	54,104	3
1963	52,101	4	57,309	30	55,004	1
1964	62,000	4	68,872	36	84,998	0
1965	43,603	3	79,852	31	97,581	0
1966	47,544	4	89,580	33	53,814	0
1967	42,425	4	126,307	36	31,154	0
1968	50,441	4	118,565	47	30,247	0
1969	67,159	4	101,115	36	29,676	0
1970	52,122	3	78,180	26	41,580	0

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Synopsis of Biological Data on the Longbill Spearfish, *Tetrapturus pfluegeri* Robins and de Sylva[1]

C. RICHARD ROBINS[2]

1 IDENTITY

1.1 Nomenclature

1.11 Valid name

The valid scientific name of this taxon is *Tetrapturus pfluegeri* Robins and de Sylva (1963:86-89).

1.12 Objective synonymy

All previous references to the species were incorrectly or incompletely attributed, mostly to the Mediterranean spearfish, *Tetrapturus belone* Rafinesque. In describing *pfluegeri,* Robins and de Sylva (1963:86, 89-90) gave complete synonymies for both species. There are no earlier invalid names nor any junior synonyms.

1.2 Taxonomy

1.21 Affinities

Tetrapturus pfluegeri has been assigned by all authors to *Tetrapturus* Rafinesque (1810) as employed by Robins and de Sylva (1960:402-406). This genus is one of three living genera recognized by those authors in the family Istiophoridae which in turn comprises with the Xiphiidae in suborder Xiphioidei of the order Perciformes.

A synonymy of *Tetrapturus* was given by Robins and de Sylva (1960:385). This is repeated below:

Tetrapturus Rafinesque

Tetrapturus Rafinesque, 1810: 54-55 (*T. belone,* type species by monotypy).

Skeponopodus Nardo, 1832: 99 (*nomen nudum);* 1833: 415-419 (*S. typus,* [= *T. belone* Rafinesque], type species by virtue of the name *typus*).

Tetrapterurus Bonaparte, 1841: 19 (emended spelling).

Tetrapterus Agassiz, 1843: 7, 89-92, table E (emended spelling).

Tetraplurus Vérany, 1847: 492-494 (misprint for *Tetrapturus*?).

Scheponopodus Canestrini, 1872: 112 (emended spelling).

Tetraperus Radcliffe, 1926: 112 (misprint for *Tetrapturus*).

Marlina Grey, 1928: 47 (*Tetrapturus mitsukurii* Jordan and Snyder, [= *T. audax* Philippi], type species by monotypy; the use of *Marlina* at the generic level is probably a slip).

Kajikia Hirasaka and Nakamura, 1947: 13-14 (*Kajikia formosana,* [= *Tetrapturus audax* Philippi], type species by monotypy).

Pseudohistiophorus de Buen, 1950: 171 (*Tetrapturus illingworthi* Jordan and Evermann [= *T. angustirostris* Tanaka], type species by original designation).

Lamontella Smith, 1956: 32 (*Tetrapturus albida* [sic] Poey, type species by original designation and monotypy).

Tetrapturus pfluegeri Robins and de Sylva

Figures 1 and 2

Type specimen.—The following designations were made by Robins and de Sylva, 1963:88. The specimen numbers in parentheses will enable the reader to obtain the morphometric data for each specimen by reference to Robins and de Sylva (1960: Tables 2, 3; 1963: Tables 1, 2). Also meristic data for the holotype were indicated by an asterisk (*) in Table 5 of the 1963 paper.

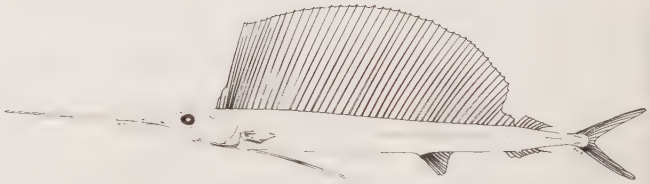

Figure 1.—*Tetrapturus pfluegeri,* juvenile, 368-mm body length, taken off Fort Lauderdale, Fla. Drawing by D. P. de Sylva (after Robins and de Sylva, 1963:Fig. 2).

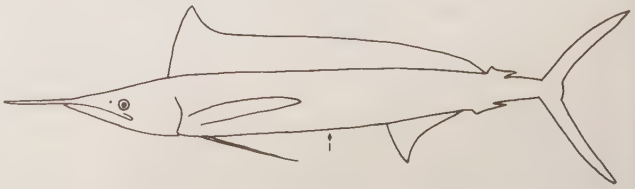

Figure 2.—*Tetrapturus pfluegeri,* adult, 1,482-mm body length, 24 lb, taken off Miami, Fla. (spec. 4, see Robins and de Sylva, 1960:392-393 for further data).

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Table 1.—Fin-ray counts of the longbill spearfish, *Tetrapturus pfluegeri*.[1]

Dorsal spines									Second dorsal rays		
45	46	47	48	49	50	51	52	53	5	6	7
1	4	6	7	11*	4	3	1	1	2	23	6*

Anal spines								Second anal rays				Pectoral rays (left fin)			
11	12	13	14	15	16	17	18	5	6	7	8	17	18	19	20
1	2	5	9	7	4*	-	1	1	11	19*	1	1	11	13	5*

[1]Data from Robins and de Sylva (1963: Table 5, supplemented by counts from specimens reported on here).

*Indicates count of holotype of *T. pfluegeri*.

Holotype.—USNM 202818, formerly UMML 2231 (spec. 5), an adult, 1,530 mm, caught by R. E. Maytag off San Juan, Puerto Rico, 1 October 1957, photo.

Paratypes.—UMML 5955, an adult, 1,790 mm, caught by M. A. Madden on 1 June 1958, east of Miami Beach, Fla., photo (spec. 15). UMML 2230, a juvenile, 914 mm, caught off Palm Beach, Fla., 23 March 1958, photo (spec. 7). UMML 5956, an adult, 1,655 mm, caught 1.5 miles off Hillsboro Light, late December 1957, or early January 1958 (spec. 8). UMML 3484 (skeleton only), 1,482 mm, caught off Miami, Fla., 14 August 1957, by S. Bergman, photo (spec. 4). Spec. 21a, 1,740 mm, female, lat. 12°38′N, long. 69°17′W, MV *Oregon* station 2764, 10 April 1960 (specimen at the American Museum of Natural History). Spec. 22, 1,620 mm, female, lat. 12°36′N, long. 63°40′W, MV *Oregon* station 2768, 14 April 1960 (specimen at the American Museum of Natural History). UMML 11095, juvenile, 368 mm (spec. 31), see data listed above and Figure 1.

Type locality.—Off San Juan, Puerto Rico.

Diagnosis.—The following is repeated from Robins and de Sylva (1963:86).

> . . . First dorsal elements 45-53 (usually 46-50), second dorsal elements 6-7 (usually 6), first anal elements 12-16 (usually 14), second anal elements 6-7 (usually 7), pectoral rays 18-20 (usually 19); second anal elements usually one more than second dorsal elements. Vertebrae 24 (12 precaudal, 12 caudal). Anus far anterior to anal-fin origin, distance 8.4-11 per cent body length (tip of lower jaw to fork of tail) and usually greater than the anterior height of first anal fin. First dorsal fin unspotted and with high profile, especially in juveniles, its 25th element varying from 17 per cent of body length (at 914-mm body length) to 7.7 per cent of body length (at 1,790 mm body length). Pectoral fin becoming proportionally longer with growth of fish (12-13 per cent of body length at 914 mm to 20-22 per cent at 1,460 mm or larger). Dorsal profile straight from origin of first dorsal-fin to a point in front of eyes. Bill long, the distance from the tip of the upper jaw to the anterior margin of the eye 27-19 per cent of body length, the lower figures characterizing the larger specimens (bill growth is negatively allometric).

Material examined.—In addition to material examined and reported on by Robins and de Sylva (1960, 1963), the writer has studied the following specimens.

Spec. 37a, 1,808 mm body length, 51 lb (23.1 kg), off Ft. Lauderdale, Fla., 19 June 1964, T. Treadway.

Spec. 38, 1,803 mm, 56.6 lb (25.7 kg), off Bakers Haulover, Dade County, Fla., 10 May 1964, M. Lojinger.

Spec. 39, 1,320 mm, 14.5 lb (6.6 kg), off Miami, Fla., 25 July 1964, G. H. Ludins.

Spec. 40, 1,617 mm, 38.8 lb (17.6 kg), off Miami Beach, Fla., March 1965.

Spec. 41, 1,616 mm, 44.5 lb (20.2 kg), off Ft. Lauderdale, Fla., 19 November 1965, Nancy Brodno.

Spec. 42, 853 mm, ca. 2 lb (0.9 kg), off Islamorada, Fla., 26 January 1966, Paul Wright.

Spec. 43, 871 mm, in surf at Miami Beach, Fla., 22 March 1965, Bud Raulston.

Spec. 44, 1,530 mm, 27.5 lb (12.5 kg), off Ft. Lauderdale, Fla., J. H. Van Ness.

Spec. 45, 1,875 mm, 60 lb (27.2 kg), off Islamorada, Fla., 15 July 1968.

Spec. 46, 1,880 mm, 80 lb (36.3 kg), off Chub Cay, Bahamas, 15 April 1971, Edwin Jay Gould.

Spec. 47, ca. 600 mm, *Oregon II,* stn. 108, lat. 12°53′N, long. 70°35′W, 23 February 1973.

During this same period other specimens from south Florida were seen and identified by the writer or de Sylva but were not measured, usually because the lower jaw was broken precluding an accurate measure of body length (= tip of lower jaw to fork of tail).

Data on specimens 37 through 47 are provided in Tables 2 and 3. In combination with previously published data this information should provide a basis for morphometric comparison with samples from the South Atlantic and elsewhere in the range for which such information is not yet available.

Synonymy.

Tetrapturus belone: LaMonte, 1955:326 (in part; reference to Florida only).—Hoese, 1958:341 (com-

Table 2.—Morphometric data for 11 specimens of *Tetrapturus pfluegeri* from the Western North Atlantic. Measurements (in millimeters) are as defined by Rivas (1956) unless otherwise indicated. Numbers in parentheses refer to the numbered definitions of Rivas; see Robins and de Sylva, 1960:384-385, for explanation of abbreviations.

Specimen number	47	42	43	39	44	41	40	38	37a	45	46
Body length (1)	600±	853	871	1,320	1,530	1,616	1,617	1,803	1,808	1,875	1,880
First predorsal length (3)	--	181	176	280	325	317	337	383	378	378	392
Second predorsal length (4)	--	699	728	1,095	1,240	1,308	1,337	1,497	1,482	1,538	1,530
Prepectoral length (5)	--	219	212	322	370	374	405	443	440	448	453
Prepelvic length (6)	--	205	222	345	395	410	423	457	468	485	491
First preanal length (7)	--	528	528	845	910	995	990	1,130	1,089	1,150	1,175
Second preanal length (8)	--	688	720	1,075	1,225	1,290	--	1,482	1,438	1,505	1,518
Orig. D_1 to orig. P_1 (9)	55	64	--	124	142	--	--	183	196	--	205
Orig. D_1 to orig. P_2 (10)	72	95	--	160	188	--	--	234	246	--	275
Orig. D_2 to orig. A_2 (11)	42	--	--	94	115	--	--	130	143	146	158
Tip mandible to anus	--	451	451	705	780	846	855	934	913	972	1,005
Orig. P_2 to nape (13)	61	117	--	173	208	--	--	250	244	--	--
Greatest body depth (14)	62	78	--	144	182	--	--	230	227	--	--
Depth at orig. D_1 (15)	58	76	87	144	182	209	207	228	227	--	252
Depth at orig. A_1 (16)	55	65	74	119	156	195	187	198	185	--	251
Least depth c. p. (17)	17	24	25	40	50	55	54	57	55	59	68
Width at P_1 base (18)	25	31	37	65	91	93	90	111	115	--	117
Width at A_1 orig. (19)	26	32	39	70	87	119	105	123	107	--	143
Width at A_2 orig. (20)	20	28	--	63	75	--	--	95	83	--	--
Width c.p. (in front of keels)	12	14	18	28	35	49	40	38	42	49	47
Length upper keel (22)	16	20	23	38	44	49	40	51	56	64	49
Length lower keel (23)	15	19	25	41	44	47	40	54	54	58	53
Head length (24)	--	213	207	364	--	367	381	433	427	433	438
Snout length (25)	--	106	102	189	183	173	192	210	221	--	--
Bill length (26)	159±	234	235+	302	343	344	374	480	391	413	403
Maxillary length (28)	--	131	132	209	235	218	246	270	272	270	272
Orbit diameter (29)	17	22	26	36	42	40	41	47	53	45	47
Depth of bill (33)	5.4	8.2	--	10	11	--	--	10	12	14	13
Width of bill (34)	6.6	9.9	--	15	17	--	--	17	19	22	22
Height D_1 (39)	108	172	152	213	292	243	273	255	265	268	273
Length 25th D_1 Spine (40)	121	143	130	--	--	146	147	--	144	130	108
Height D_2 (41)	21	29	28	53	56	94	72	72	61	63	--
Height A_1 (42)	50	82	83	129	184	143	188	150	162	158	176
Height A_2 (43)	16	21	26	40	52	51	55	51	55	57	48
Length P_1 (44)	58	118	114	249	345	356	378	360	371	403	375
Length P_2 (45)	140	--	160	295±	342	354	--	--	367	403	--
Length last D_2 ray	23	37	40	69	92	63	103	104	93	106	--
Length last A_2 ray	24	36	42	67	78	91	94	104	92	95	92
Orig. D_1 + Orig. D_2	381	546	562	830	930	973	998	1,139	1,133	1,170	1,185
Anus to orig. A_1	55	77	80	115	136	154	139	179	173	176	183
Weight (lb)	1.1	2	--	14.5	27.5	44.5	38.8	56.5	51	60	80

piled; Texas).—Migdalski, 1958:70 (Puerto Rico and Florida; lower figure opposite p. 100 except for fish at upper right).—Robins and de Sylva, 1960 (in part; diagnosis, description, and data on *belone* in Tables 1-3, and Figs. 1, 2, 3b, 4 entirely referable to *pfluegeri*; those items in synonymy which are based solely on Mediterranean specimens or accounts and discussion based on photographs of Mediterranean specimens are not referable to *pfluegeri*).—Tortonese, 1962:8-9 (in part; information referring to Florida only).—Cavaliere, 1962:171 (in part; reference to western Atlantic material reported by Robins and de Sylva, 1960).—Peronaci, 1966 (in part, Atlantic references only; *T. pfluegeri* regarded to be synonym of *T. belone*).

Young *Makaira:* LaMonte, 1955:346-347 (fish taken in "spring of 1939 half-way between Bimini, Bahamas and Miami, Florida").

Spearfish, Swann, 1957:15, 28 (photograph of specimen captured off Port Aransas, Texas; subsequently reported on by Springer and Hoese [1958] as *Tetrapterus belone* [?] and listed by Hoese [1958] as *Tetrapturus belone*).

Tetrapterus belone: Robins, 1958:16 (in part, Florida only).

Tetrapterus belone (?): Springer and Hoese, 1958:345-346 (Port Aransas, Texas; measurements, counts, coloration).

Table 3.—Morphometric data for 11 specimens of *Tetrapturus pfluegeri* from the Western North Atlantic expressed in percentage of body length. Measurements are as defined by Rivas (1956) unless otherwise indicated. Numbers in parentheses refer to the numbered definitions of Rivas; see Robins and de Sylva, 1960:384-385, for explanation of abbreviations.

Specimen number	47	42	43	39	44	41	40	38	37a	45	46
Body length (1)	[1]600±	853	871	1,320	1,530	1,616	1,617	1,803	1,808	1,875	1,880
First predorsal length (3)	--	21	20	21	22	20	21	21	21	20	21
Second predorsal length (4)	--	82	84	83	81	81	83	83	82	82	81
Prepectoral length (5)	--	26	24	24	24	23	25	25	24	24	24
Prepelvic length (6)	--	24	25	26	26	25	26	25	26	26	26
First preanal length (7)	--	62	61	65	60	62	61	63	60	61	62
Second preanal length (8)	--	81	83	81	80	80	--	82	80	80	81
Orig. D_1 to orig. P_1 (9)	9.2	7.6	--	9.4	9.3	--	--	10	11	--	11
Orig. D_1 to orig. P_2 (10)	12	11	--	12	12	--	--	13	14	--	15
Orig. D_2 to orig. A_2 (11)	6.9	--	--	7.2	7.5	--	--	7.2	7.9	7.8	8.4
Tip mandible to anus	--	53	52	53	51	52	53	52	50	52	54
Orig. P_2 to nape (13)	10	14	--	13	14	--	--	14	14	--	--
Greatest body depth (14)	10	9.1	--	11	12	--	--	13	13	--	--
Depth at orig. D_1 (15)	10	8.9	10	11	12	13	13	13	13	--	13
Depth at orig. A_1 (16)	9	7.6	7.4	9.1	10	12	12	11	10	--	13
Least depth c.p. (17)	2.9	2.8	2.5	3.0	3.3	3.4	3.3	3.2	3.0	3.1	3.6
Width at P_1 base (18)	4.1	3.6	4.2	4.9	5.9	5.8	5.6	6.1	6.4	--	6.2
Width at A_1 orig. (19)	4.3	3.8	4.5	5.3	5.7	7.4	6.5	6.8	5.9	--	7.6
Width at A_2 orig. (20)	3.4	3.3	--	4.7	4.9	--	--	5.3	4.6	--	--
Width c.p. (in front of keels)	3.8	1.6	2.1	2.1	2.3	3.2	2.5	2.1	2.3	2.6	2.5
Length upper keel (22)	2.7	2.3	2.6	2.9	2.8	3.2	2.5	2.8	3.1	3.4	2.6
Length lower keel (23)	2.3	2.2	2.9	3.1	2.8	2.9	2.5	3.0	3.0	3.1	2.8
Head length (24)	24	25	23	28	--	23	24	24	24	23	23
Snout length (25)	--	12	12	14	12	11	12	12	12	--	--
Bill length (26)	26	27	27	23	22	21	23	27	22	22	21
Maxillary length (28)	--	15	15	16	15	14	15	15	15	14	14
Orbit diameter (29)	2.8	2.6	3.0	2.7	2.7	2.5	2.5	2.6	2.9	2.4	2.5
Depth of bill (33)	1.1	0.9	--	0.7	0.7	--	--	0.6	0.7	0.7	0.7
Width of bill (34)	--	1.1	--	1.1	1.1	--	--	0.9	1.0	1.2	1.2
Height D_1 (39)	18	20	17	16	19	15	17	14	15	14	14
Length 25th D_1 Spine (40)	20	17	15	--	--	9.0	9.1	--	8.0	6.9	5.7
Height D_2 (41)	3.5	3.4	3.2	4.0	3.7	5.8	4.4	4.0	3.4	3.4	--
Height A_1 (42)	8.3	9.6	9.5	9.8	12	14	12	8.3	9.0	8.4	9.4
Height A_2 (43)	2.8	2.5	3.0	3.0	3.4	3.2	3.4	2.9	3.0	3.0	2.6
Length P_1 (44)	10	14	13	19	22	22	23	20	20	22	20
Length P_2 (45)	23	--	18	22±	22	22	--	--	20	22	--
Length last D_2 ray	3.8	4.3	4.6	5.2	6.0	3.9	6.4	5.8	5.1	5.6	--
Length last A_2 ray	4.0	4.2	4.8	5.1	5.1	5.6	5.8	5.8	5.1	5.1	4.9
Orig. D_1 + orig. D_2	63	64	64	63	61	60	62	63	63	62	63
Anus to orig. A_1	10	9.0	9.2	8.7	8.9	9.5	8.6	9.9	9.6	9.4	9.7

[1]Mandible broken, percentages approximate.

Tetrapturus beloni [sic]: Briggs, 1958:287 (listed from Florida; distribution, habitat).

Tetrapterus . . . . . Robins, 1958:17 (southeastern Florida).—Erdman and Roman, 1959:figure on p. 117 (Puerto Rico).

Tetrapturus sp. Migdalski, 1958:70-71, lower figure opposite p. 100, except for fish in upper right (Florida and Texas).

Tetrapturus pfluegeri Robins and de Sylva, 1963:86-89, Tables 1, 2, Figs. 1, 2 (original description; distinguished from *T. belone*).—De Sylva, 1963:125, 130 (juvenile compared to other Atlantic species). Anon., 1963:53 (review of original account of species); 1964a:40 (one reported caught during operations of MV *Delaware* off New England); 1964b:31 (one reported caught during operations of MV *Delaware* between North Carolina and Georges Bank).—Ueyanagi and Watanabe, 1965 (differences in vertebral column between various istiophorids including *T. pfluegeri*).—Nakamura, Iwai, and Matsubara, 1968 (review of history and morphometry; new data provided on Atlantic distributions of adults and larvae and on various aspects of anatomy).—Ovchinnikov, 1970 (recorded from Caribbean Sea; various notes on eye size, swimming capability).—Ueyanagi et al., 1970:21-23, Figs. 7, 9-11 (geographical and seasonal distribution of adults and larvae, notes on maturity).—Anon., 1972:40 (photograph of 22-lb (10.0-kg) specimen from off Dade County,

Fla.—Penrith and Talbot, 1973 (morphometry of two specimens taken northwest of Capetown in the southeastern Atlantic).—Wise and Davis, 1973:20 (comments on meaning of Japanese longline data regarding this species).

A key to all istiophorid species was presented by Robins and de Sylva (1960) based on all species known at that time. Since then *Tetrapturus pfluegeri* was described and *T. georgei* resurrected. De Sylva (1974) in his summary of information for *Tetrapturus belone* has presented a revised and inclusive key to all species of *Tetrapturus.*

1.22 Taxonomic status

The taxonomic status of *T. pfluegeri* is clear insofar as the juveniles and adults are easily distinguished from all other billfishes. Its distinctive morphology establishes its species status. Only Peronaci (1966) among recent writers has failed to perceive its distinctiveness. Virtually all morphometric data available on *pfluegeri* are from the western Atlantic and especially Florida. There is no basis for commentary on geographic variation except that manuscript data on two specimens from South Africa from Penrith and Talbot (1973), kindly provided by M. J. Penrith, show perfect agreement with Florida specimens of comparable size from the opposite end of the range of the species. This plus experience with related species strongly suggests that we should not expect noteworthy geographic variation in the species. This does not mean that less obvious but measurable differences might not exist.

1.23 Subspecies

No subspecies are recognized.

1.24 Standard common names and vernacular names

The standard name for the species (Bailey et al., 1970) is longbill spearfish, the name originally attributed to it by its describers. It is known by anglers that recognize it by this name or simply as spearfish. The Japanese name is Kuchinaga-furai (see Howard and Ueyanagi, 1963) or Kuchinagufurai (Wise and Davis, 1973:2). The Soviet literature terms it malyi kop'enosets. Other names are those loosely applied to any of the billfishes.

1.3 Morphology

Fin rays.—T. pfluegeri has a high dorsal spine count 45-53, usually 48-51. Care must be taken to count the last one or two which may be imbedded in the skin anterior to the second dorsal fin in large adults. No other Atlantic istiophorid has such a high count. There are usually 6 (rarely 7) second dorsal and usually 7 (occasionally 6 and rarely 8) second anal rays. There are 12-18 (usually 13-10) elements in the first anal fin. Pectoral rays vary from 17 to 20, but are most frequently 19. Variation in fin ray counts may be seen by reference to Table 1, which is based on data from Robins and de Sylva (1963), supplemented with data reported for the first time in Tables 2 and 3.

Vertebrae.—As with all species of *Tetrapturus* there are always 24 vertebrae divided equally between precaudal and caudal, the division sharply defined (see Nakamura et al., 1968, Fig. 7). The vertebral column of *pfluegeri* is illustrated by Ueyanagi and Watanabe (1965:pl. 3a, b).

Fins.—The spinous dorsal fin is high throughout in small juveniles tapering sharply downward at the last several elements. A slight dip forms behind the anterior lobe in larger juveniles, but the posterior part of the fin never exceeds the height of the anterior lobe as it does for example in *Istiophorus.* In adults the height of the fin fades away from the anterior lobe but is higher than in *T. albidus* and notably higher than in species of *Makaira* nearly to its end. Apparently the posterior section of the fin ceases to grow at a body length less than 900 mm. This can easily be seen in Robins and de Sylva (1960:Fig. 2, lowermost section). The pectoral fin is positively allometric being short (12-14% of body length) in juveniles and long (20-22% of body length) in adults. The transition is sharp and specimens of about 1,000- and 1,300-mm body length could easily be thought to be separate species on this basis.

The first anal fin is low, decidedly less than the body height at that point and pointed.

Bill.—The bill, as with all species of *Tetrapturus,* is proportionally longest in juveniles, shorter in adults. The name longbill spearfish was used to contrast this species from its closest allies, the Mediterranean spearfish, *T. belone,* and the shortbill spearfish, *T. angustirostris,* both of which are short snouted. The bill in *T. pfluegeri* is shorter than that of the white marlin, *T. albidus,* or the sailfish, *Istiophorus platypterus.*

Dorsal profile.—The profile is straight from the base of the bill to the origin of the dorsal fin; this species thus lacks the humped nape of *T. albidus.*

Color.—The color is dark bluish black above, silvery on the sides, and whitish below; the membrane of the spinous dorsal fin is bright blue without dark spots. Vertical barring is never prominent though pale bars are usually visible when a specimen is freshly caught. Juveniles have a dark blotch from the base of the 16th to the 17th dorsal spines.

There has been no published report on cytomorphology or protein specificity and only scattered information on internal morphology. Nakamura et al. (1968) report generally on the inter-

nal anatomy of billfishes using various species including *pfluegeri* to illustrate their points. The gonads are assymetrical (Y-shaped) in *pfluegeri.*

Tetrapturus pfluegeri was described in detail by Robins and de Sylva (1960) under the name *T. belone* and later (1963) diagnosed and distinguished from *belone* and other species. Nakamura et al. 1968:62-63 also summarize its morphology.

2 DISTRIBUTION

2.1 Total Area

Tetrapturus pfluegeri was originally reported (under the name *T. belone*) in the western Atlantic from Maryland to Venezuela including the entire Gulf of Mexico and Antillean region (Robins and de Sylva, 1960:Fig. 4). In formally describing the species, Robins and de Sylva (1963:88) extended the range to New Jersey. It was then reported from off New England (Anon., 1964a) and from somewhere between North Carolina and Georges Bank (Anon., 1964b). Japanese longlines have taken it repeatedly and in the north central and South Atlantic from southeastern Brazil to South Africa (see especially Ueyanagi et al., 1970:Fig. 7). Most recently it has been recorded from South Africa (125 miles northwest of Cape Columbine) by Penrith and Talbot (1973).

Some of the Japanese data may be based on the roundscale spearfish, *T. georgei,* only recently diagnosed (Robins, 1974), but it is clear that *T. pfluegeri* is wide ranging in the Atlantic Ocean and perhaps is most common in the mid- or South Atlantic. Other recent references in sporting magazines are all from within the described range.

When this species was described and brought to the attention of anglers in the Florida region, I was confident that the recognition would result in more being brought to the taxidermy shops. Captains and guides do recognize the fish but catches remain few. The only difference is that most now coming to the shops are correctly identified. I can only conclude that relative to other istiophorid species in the area, *T. pfluegeri* is truly rare in waters of the Bahamas and the United States. Whether it will prove more common in the mid- or South Atlantic is unknown. Hook rates are highest (Ueyanagi et al., 1970:Fig. 7) in these regions and in the Caribbean, but such data cannot be assessed without knowing the actual numbers of hooks set and the total numbers of the various fishes caught. Highest hook rates could be experienced with the fewest hooks out and a small catch.

In summary, *T. pfluegeri* ranges widely through the Atlantic from about lat. 40°N to 34°S and from New England, Texas, and southeastern Brazil to between long. 20° and 25°W and the Cape Verde Islands in the North Atlantic and to South Africa in the South Atlantic. It is not yet known to occur in African waters north of South Africa.

2.2 Differential Distribution

In data provided by Ueyanagi et al., 1970 (Figs. 7, 9-11) it is apparent that the size distribution is similar for the 11 geographic areas analyzed (see their Fig. 1) with the possible exception of areas C and F. Here samples are small and these two areas, the most eastern in the North Atlantic, are those where misidentifications of *T. georgei* are most likely to have occurred. Similarly there is no noteworthy difference in sex ratios although males may be more common in the north and west. Mature individuals were taken only in the January-March and April-June quadrants with the exception again of the area around the Cape Verde Islands and of the Caribbean where some mature individuals are recorded in October-December. In most instances these data are based on small samples. Mature individuals were not recorded north of lat. 20°N in the western Atlantic nor south of lat. 30°S. Surprisingly, maturation occurs at the same time rather than at the same season both in the northern and southern hemisphere. More than any other factor, this is suggestive of homogeneity of stock.

2.4 Hybridization

There is no morphological indication that *T. pfluegeri* hybridizes with any of its relatives. Robins (1974) considered and rejected the possibility that *T. georgei* as defined by him could be based on hybrids between *T. pfluegeri* and *T. albidus.*

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

Sexes are separate in the longbill spearfish. There is no demonstrated sexual dimorphism in the morphometry of *T. pfluegeri,* nor is there any evidence of hermaphroditism.

3.12 Maturity

There has been no published study on age and growth nor age at maturity. Data from Japanese longline catches suggest that spawning occurs in late winter. This is based on their notes on seasonal occurrence of mature individuals. Looking at all available data, spawning no doubt occurs between late November and early May with a peak perhaps in late winter. To provide some answers to the question of age and growth the writer has assumed that spawning occurs in mid-February (15 Feb.) and has then grouped length and weight data from all specimens examined by him by month from that point. This was done twice, once by using the length data alone, the

second time using weight data alone. In only one instance was a spot placed differently. The results are seen in Figure 3 and indicate the presence of at most four year classes (0, I, II, III). One-year-old fish (beginning of year class I) can be expected to be about 800 to 1,000 mm in body length and 4 to 6 pounds. Two-year-old fish are about 1,600 to 1,770 mm in body length and 38 to 41 pounds. Three-year-old fish are not much longer, about 1,800 mm body length, but are heavier, 60 to 80 pounds. First spawning would occur at the end of the second year and few fish apparently survive beyond a second spawning a year later, assuming that the species spawns but once per year. A short life history is not surprising and this fit of the data seems most parsimonious. That is, attempts to fit the data to five instead of four year classes on the basis of length or weight result in greater inconsistencies in the other parameter than those exhibited in Figure 3. The variation seen is remarkably small considering that a point-in-time spawning was assumed when in fact spawning no doubt occurs over several months.

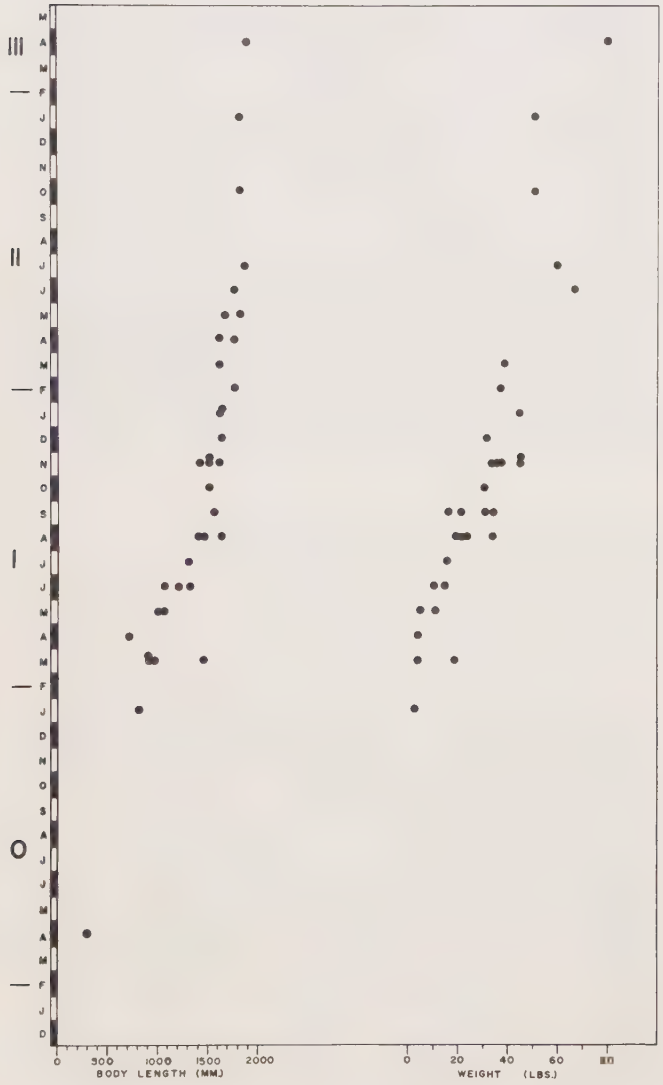

Figure 3.—Age and growth analysis of *Tetrapturus pfluegeri* basd on data from the sport fishing catch in the western Atlantic. (Year classes 0, I, II, and III and months of the year are indicated on the ordinate. The assumed spawning time is indicated by the horizontal line at mid-February. See text for explanation.)

The writer also has available length data from the Pflueger taxidermy shop records; this information was provided by Donald P. de Sylva. Lengths are in 2-inch increments and are measured from the rear margin of the eye to the fork of the tail. These data gathered from 1958 to 1967 include some of the same fish analyzed by the writer, especially prior to 1964. The results are similar to those above and show 4-yr groupings. Because of the overlap in specimens and different means of measurement these data are not further treated.

3.13 Mating

Whether spawning is in pairs or larger groups is unknown.

3.14 Fertilization

Nothing is known of the reproductive behavior nor of fecundity. Fertilization surely is external and females probably spawn but once during the year. The eggs have not been described.

3.15 Gonads

The ovaries are unequally developed, that of the left side being approximately twice that of the right. The right meets the left at an angle about half way back, the result is that the ovary appears Y-shaped when first seen, the stem of the Y pointing forward. In specimen 45 (see material examined above) the left ovary was 475 mm, the right 230 mm; in specimen 41 these measurements are 458 and 242 mm. On the other hand the left ovary in specimen 35 was 193 mm, the right 212 as determined by W. P. Davis. The testes are similarly asymmetrical, again the left side being longer. In specimen 27 the two measured 65 and 30 mm and in specimen 14 (see Fig. 4) the two are 205 and 110 mm. A study of changes in gonad size and shape with maturation is needed. In those specimens with asymmetrical gonads the junction point of the "Y" is almost directly above the anus. Merrett (1970:357, pl. 16) notes that of all istiophorids examined by him in the Indian Ocean, only *T. angustirostris* Tanaka has asymmetrical gonads and that the left is the longer, the junction being at the level of the urogenital operture.

3.2 Preadult Phase

De Sylva and Ueyanagi, on the occasion of the International Billfish Symposium at Kona, August 1972, showed slides of larvae which they identified as

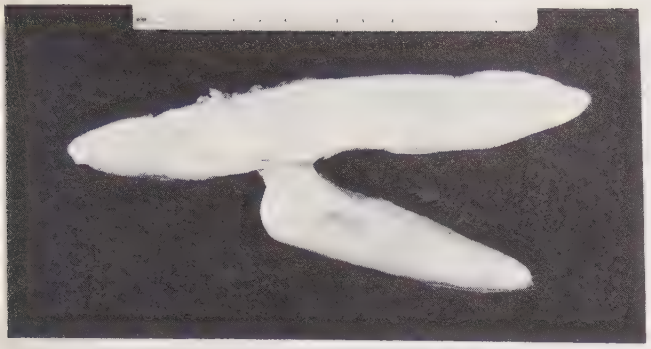

Figure 4.—Testes of *Tetrapturus pfluegeri*, 1,577-mm body length, 34 lb, taken off Fort Lauderdale, Fla., 25 September 1958 (spec. 14).

T. pfluegeri. This work, to be submitted to the Dana Reports, is not yet in press. There is no published information on the early development of *pfluegeri.* De Sylva (1963:125, 130) has compared the juvenile (the same individual shown in Fig. 1) with those of the *Tetrapturus albidus, Istiophorus albicans* (=*I. platypterus*), and *Makaira nigricans.*

3.3 Adult Phase

3.31 Longevity

As noted in 3.1 and in Figure 3, few fish are more than 3 yr old (age class II). However, this is theoretical and no detailed age and growth study has been made.

3.4 Nutrition and Growth

Ovchinnikov (1970:Table 7) reported on stomach contents of specimens from northeastern Brazil. These data differ from those given for white marlin and Atlantic sailfish from the same region. Unfortunately incidence of a food item is reported only in percent of total numbers of stomachs examined and inasmuch as no item appeared in fewer than 11% of the stomachs, we must conclude that only nine stomachs were studied, a small sample for this type of study. All but one of the food items are of the type that is found at or near the surface and under drift materials. *Alepisaurus* sp. is reported from 22.5% of the stomachs (2 stomachs?). Presumably a gempylid was involved instead.

It is expected that *T. pfluegeri* feeds on small and medium-sized fishes and cephalopods in surface waters and that availability will largely determine the nature of the composition of the diet from place to place or season to season.

3.5 Behavior

Nothing is known of migrations or local movements. In southeastern Florida where there is good sport fishing effort throughout the year, fish have been taken in every month. The species seems always to be present though in small numbers. There is no known area of postspawning aggregations as is the case with the white marlin. The scarcity of fish makes any tagging program unfeasible.

3.52 Schooling

Fishermen have experienced on several occasions a "double-header," that is, a situation where two fish cross the stern and take both trolled baits. Such pair formation is known for other billfishes and is common in the dolphin, *Coryphaena hippurus.* Sexes of the paired fish are unknown and frequently only one of the two involved is boated. In *C. hippurus,* the pair is usually but not always male and female. Such pair formation is more likely related to hunting procedure.

4 POPULATION

4.1 Structure

4.11 Sex ratio

Most fish examined at taxidermy shops have the internal organs soft, largely disintegrated in the case of the gonads. For this reason we have few specimens for which sex determination is positively given. Of 18 such identifications 9 each were male and female. Presumably the sex ratio is 1:1 as these few data suggest.

4.12 Age composition

For reasons explained above most of the population consists of year classes 0, I, and II, few fish entering year class III. They enter the sport fishery when they are 1 yr old and probably mature at about their second birthday. Maximum age is currently indicated at less than 4 yr, but there is no appreciable growth at this age and a few fish may live another year.

Beyond this nothing is known of population structure.

5 EXPLOITATION

5.1 Fishing Equipment

5.11 Gears

The longbill spearfish is fished by anglers in the same manner that they fish for other billfishes. No one specifically fishes for spearfish. Gear and tackle preferences vary but all are well documented in the sport fishing literature. Large baits such as those used by some anglers for blue marlin will not succeed with the much smaller spearfish. As many as 10 fish per year are sent to each of the two principal taxidermy

shops in southeastern Florida. Catches everywhere are low and probably fewer than 100 spearfish per year are caught by anglers in the western Atlantic.

Commercial longlining vessels take spearfish along with tunas, swordfish, other istiophorids, sharks, and miscellaneous other fishes. Again spearfish catches are incidental and the gear used is well described in various trade and government journals. Japanese data grouped spearfish and sailfish under "other marlin" until 1965, and since that time have listed them as "spearfish and sailfish." These data may include small marlin. It is assumed by Japanese biologists, as noted by Wise and Davis (1973:20), that nearshore records apply to sailfish, offshore records to spearfish. There is no valid reason to exclude spearfish from nearshore catches and no doubt some sailfish are included in the offshore data. Wise and Davis (1973:3) record 610,000 fish in this category caught between 1958 and 1969 with peak years of 118,000 in 1964 and 1965, the years of maximum Japanese effort, about 85 and 97.5 million hooks. Even assuming that only a small percentage are spearfish it is obvious that many more spearfish are caught commercially than by sport fishermen.

5.12 Boats

Fishing vessels, whether for sport fishing or longlining are those generally employed for the purpose and are well described in the voluminous literature on the subject.

5.2 Fishing Areas

5.21 General geographic distribution

See 5.22.

5.22 Geographic ranges

Inasmuch as all fish studied were obtained by the sport fishery or the longline fishery, it follows that the known distribution of the species, described in detail above, is that of the fishery.

The sport fishery is restricted by logistical reasons to coastal areas near ports where marina facilities exist for private yachts and where charter boats are available. Oceanic big game fishing is an expensive pastime and except for some coastal cities in the United States at which relatively inexpensive charters are available, most participants are from upper and middle income groups. Therefore, the main sport fishing centers for all istiophorid fishes are coastal tourist cities and islands with first-class tourist accommodations. Few boats fish more than 50 miles from port except along the southeastern coast of Brazil where operations may extend beyond 200 miles. Recently sport fishing boats, fishing out of St. Petersburg, Fla., and using a mother ship, have fished over the 100-fathom curve about 100 miles from shore (de Sylva, pers. comm.).

In contrast the longline fishery is largely oceanic. The extent of this fishery is easily seen by the examination of the numerous charts in Ueyanagi et al. (1970). Specifically Figure 7 in that work shows the geographic distribution of catches of the longbill spearfish, but the charts of the other more common istiophorids such as the blue and white marlins give a better view of the geographic distribution of the fishing effort.

6 PROTECTION AND MANAGEMENT

No data.

7 POND FISH CULTURE

Not applicable.

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Synopsis on the Biology of the Shortbill Spearfish, *Tetrapturus angustirostris* Tanaka, 1914 in the Indo-Pacific Areas

SHOJI KIKAWA[1]

1 IDENTITY

1.1 Nomenclature

1.11 Valid name

Tetrapturus angustirostris Tanaka, 1914 (Fig. 1).

Original description: Tanaka, Shigeho. 1914-1915. Figures and descriptions of the fishes of Japan. Daiichi Shoin, Tokyo 18:295-318 (1914); 19:319-342 (1915).

1.12 Objective synonymy

All synonyms that appear in the literature seem to be subjective (See 1.21 below).

1.2 Taxonomy

1.21 Affinities

Suprageneric

Phylum Chordata
Subphylum Vertebrata
Superclass Gnathostomata
Class Osteichthyes
Subclass Actinopterygii
Order Perciformes
Suborder Xiphioidei
Family Istiophoridae

Generic

Genus *Tetrapturus* Rafinesque, 1810.

Original description: Rafinesque, C. S. 1810. Carratteri di alcuni nuovi generi e nuove specie di animali principalmente di pesci e piante della Sicilia, con varie osservazioni sopra i medesimi. 105 p. Palermo.

The generic concept of *Tetrapturus* has been a confused one. Hirasaka and Nakamura (1947) divide Istiophoridae into two subfamilies, Tetrapturinae and Marlinae. They place *Tetrapturus, Istiophorus,* and *Kajikia* in the former, and *Marlina* and *Eumakaira* in the latter. In *Tetrapturus,* they include a single species, *T. angustirostris,* and state that *T. belone* in the Mediterranean Sea and *T. brevirostris* in the Indian Ocean may be the same species, or very closely related. Their genus *Kajikia* embraces two species, *K. mitsukurii* (Jordan and Evermann), the Indo-Pacific striped marlin, and *K. formosana,* new species, which was shown later by Ueyanagi (1957) to be the juvenile form of the striped marlin.

Matsubara (1955) disagrees with Hirasaka and Nakamura (1947) and states that the number of vertebrae and other diagnostic characters they used to establish the subfamilies do not deserve a generic rank. Matsubara also considers *Makaira* as valid and excludes *Kajikia, Marlina,* and *Eumakaira* as synonyms of *Makaira.* According to his classification of Japanese fishes, *Tetrapturus* includes *T. angustirostris,* and *Makaira* includes four species: *M. mitsukurii* (Jordan and Evermann), the Indo-Pacific striped marlin; *M. formosana,* now a synonym of *M. mitsukurii; M. mazara* (Jordan and Snyder), the Indo-Pacific blue marlin; and *M. marlina* Jordan and Hill, the black marlin.

LaMonte (1955) states that *Tetrapturus* can be distinguished from *Makaira* by its much more slender body, shorter spear, shorter pectorals, lower lobed and evenly high dorsal, and smaller caudal span. She recognizes *T. belone* Rafinesque, the Sicilian fish, and *T. angustirostris* Tanaka as valid species of the genus.

Royce (1957), who analyzed morphometric data from specimens taken in the central Pacific Ocean, states that the variation in the height of the dorsal lobe and the length of the pectoral fins is such that these characters are not useful in distinguishing one species from another.

With regard to Tetrapturinae and Marlinae as set forth by Hirasaka and Nakamura (1947), Robins and de Sylva (1960, 1963) support this basic dichotomy but state that these subdivisions need not be accorded subfamily rank. To such definitions, they add the character of negative allometry of the snout in the "Tetrapturinae" and positive allometry in the "Marlinae," but deny the aid of the pectoral fins for generic definition because this character, mainly on the basis of which LaMonte separates *Tetrapturus* from *Makaira,* shows marked allometry in the spearfish. Robins and de Sylva state that *T. angustirostris,*

[1]Far Seas Fisheries Research Laboratory, Shimizu, Japan.

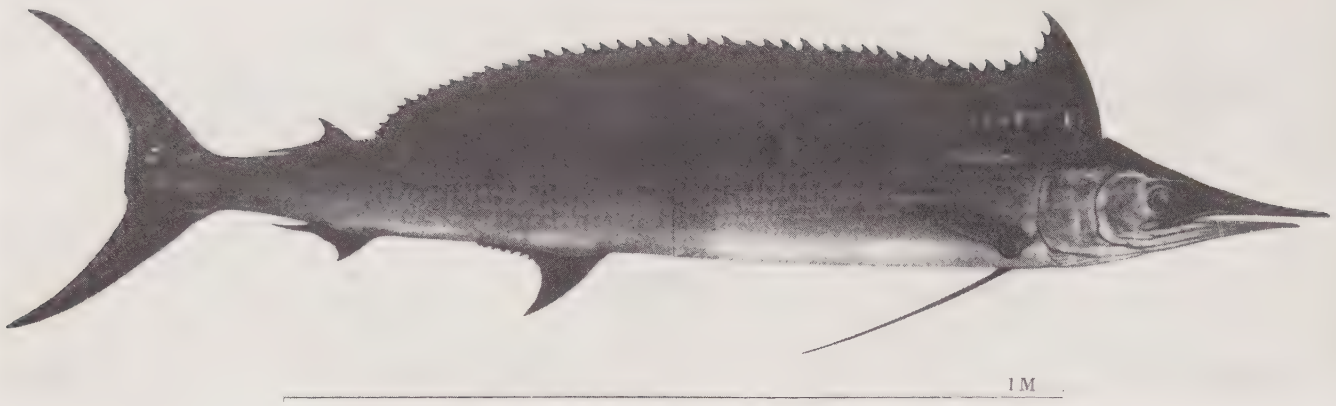

Figure 1.—*Tetrapturus angustirostris* Tanaka, 1914 (from Hirasaka and Nakamura, 1947).

T. belone, T. pfluegeri, T. albidus, and *T. audax* form a series of equally distinct species. They also point out that the placement of *T. albidus* and *T. audax* in *Makaira* is not in accordance with their relationship because they must be more closely associated with *T. angustirostris* and *T. belone* and indeed with *Istiophorus* than with any of the Makairinae (= Marlinae). These authors feel that the characters separating the above five species do not deserve even subgeneric rank and conclude that all should be placed in the genus *Tetrapturus.*

Morrow (1964) agrees with Robins and de Sylva (1960, 1963) in placing *T. angustirostris* nearer to the Atlantic and Pacific billfishes, the striped marlin, and the white marlin than to the blue marlin and the black marlin in the phylogeny of the Istiophoridae.

The basic dichotomy in recognizing the Istiophoridae, viz. the *Tetrapturus* type and *Makaira* type (*Makaira* as constituted by Robins and de Sylva, 1960), is also supported by Ueyanagi (1963b). He confirms that, for the growth of the snout, *Tetrapturus* and *Istiophorus* have a positive allometry during the larval stage[2] and a negative allometry after the young stage,[2] while *Makaira* has a positive allometry after the young stage. The same subdivision, according to Ueyanagi, is also true of the morphological change in the dorsal fin.

Howard (in Howard and Ueyanagi, 1965) mentions that Nakamura's divisionary characters may have some phylogenetic value and feels that the hierarchy proposed by Robins and de Sylva, which takes into consideration the only presently known characters which may have phylogenetic significance, is the most usable and practical offered so far.

Nakamura, Iwai, and Matsubara (1968) include three genera, *Istiophorus*, *Tetrapturus*, and *Makaira*, in the Istiophoridae. They separate *Istiophorus* from the other two by its much higher, saillike first dorsal fin and considerably elongated ventral fins with well-developed fin membrane. The distinguishing characters between *Tetrapturus* and *Makaira* are the height of the first dorsal fin, the degree in lateral compression of the body and the dorsal profile from the preocular region to the first dorsal origin. They place in *Tetrapturus* not only the spearfish group of the world, but also the Indo-Pacific striped marlin and white marlin, and thus agree with Robins and de Sylva (1960, 1963).

The generic concept of *Tetrapturus* has, as seen above, changed from what originally referred only to the spearfish group to where it now includes species ranging from the shortbill spearfish to the Indo-Pacific striped marlin. Most authors have used the form of the dorsal fin and the nature of the ventral fins in separating *Istiophorus* from *Tetrapturus*. The dichotomous system discussed above puts *Istiophorus* nearer to *Tetrapturus* rather than to *Makaira*, but it appears that there is current agreement that these fin characters deserve generic rank although the form of the first dorsal fin changes considerably with growth.

The diagnostic characters of *Tetrapturus*, especially for adults, given by Nakamura et al. (1968) are as follows:

> The first dorsal fin is slightly higher than the body depth. The ventral fin rays are rather long, its fin membrane not well developed. The body is laterally compressed. The dorsal profile is straight from the preocular region to the origin of the first dorsal fin, except for the striped marlin and the white marlin. The cranium is narrow in width and slender. The neural and haemal spines on the central vertebrae nearly form a parallelogram. The number of vertebrae are 12 + 12 = 24. The lateral apophysis is not well developed.

Specific

Species *Tetrapturus angustirostris* Tanaka, 1914. (Fig. 1)

(Original combination)

Identity of type specimen:

Length: 2,000 mm measured from tip of spear to upper lobe of caudal.

[2]For these definitions, see Ueyanagi (1963a).

Deposited at: Science College Museum, Tokyo University.
Catalog No.: 4187.
Reported by: Shigeho Tanaka.

Type locality: Sagami Bay, southern coast of central Japan.

Diagnosis:

1. The snout is very short and the body deeply compressed.
2. The first dorsal fin at the anterior lobe is nearly the same as the body depth, then being evenly high posteriorly.
3. The second anal fin is situated anterior to the second dorsal fin.
4. The pectoral fins are narrow and short.
5. The anus is situated far anterior to the origin of the first anal fin.
6. The number of first dorsal spines ranges from 46 to 50.
7. A paired gonad is asymmetrical and Y-shaped, the left lobe is much longer.

Subjective synonymy:

Tetrapturus illingworthi Jordan and Evermann, 1926.
Tetrapturus kraussi Jordan and Evermann, 1926.
Tetrapturus brevirostris Fowler, 1928.
Psudohistiophorus angustirostris de Buen, 1950.
Psudohistiophorus illingworthi de Buen, 1950.
Tetrapturus indicus Deraniyagala, 1951.

Artificial key to genus: The following key to the species of *Tetrapturus* is based on Nakamura et al. (1968), who constructed a key to all the species of the Xiphiidae and Istiophoridae.

a_1 First dorsal fin is rather high at the anterior part, being nearly at the same height to the posterior. Anus situated far anterior to the origin of first anal fin. Second anal fin situated anterior to the second dorsal fin.
  b_1 Pectoral fins narrow and short . . . . . *T. angustirostris* Tanaka
    c_1 Snout remarkably short . . . . . *T. belone* Rafinesque
  b_2 Pectoral fins broad and long . . . . . *T. pfluegeri* Robins and de Sylva

a_2 First dorsal fin is slightly higher than, or nearly the same as, body depth at the anterior part, then gradually lowered. Anus situated just anterior of the origin of first anal fin. Second anal fin and second dorsal fin nearly opposite.
  d_1 Pectoral fins broad with rounded tip. Tip of first dorsal fin and first anal fin roundish . . . . . *T. albidus* Poey
  d_2 Pectoral fins narrow with pointed tip. Tip of first dorsal fin and first anal fin pointed . . . . . *T. audax* (Philippi)

1.22 Taxonomic status

Recent morphometric studies on external characters of *T. angustirostris* suggest that there may be clinal or population variations in some of these characters among specimens from different oceans. It seems natural, therefore, to think it polytypic (see 1.31).

1.23 Subspecies

None.

1.24 Standard common names and vernacular names

Country	*Standard common name*	*Vernacular name*
Japan	Furaikajiki	Sugiyama Sanmakajiki
United States	Shortbill spearfish	Shortnose spearfish Slender spearfish
Latin America	Pez aguja corta	

1.3 Morphology

1.31 External morphology

Generalized: The billfishes are generally large and elongate, and are usually characterized by a long projected spearlike snout (the snout is as long as 30% of the eye-fork length or more, except for the shortbill spearfish, which is the only species with an especially short snout). The ventral fins are more or less diminished. Other fins, especially the caudal fin, are well developed. The form of the first dorsal fin varies markedly according to the species. The vertebral bones are peculiar in structure with well-developed platelike neural and haemal spines and characteristically extended anterior neural and anterior haemal zygapophyses. The number of vertebrae are 24 (12 + 12 or 11 + 13) (Ueyanagi, 1963b).

The external morphology of *T. angustirostris* as described by Nakamura et al. (1968) is as follows:

ID, XLVII-L; IID, 6-7; IA, 12-15; IIA, 6-7; P, 18 - 19; V, I, 2. Body elongate and very laterally compressed (body length about 16.1-22.2 times body width). Body height remarkably low (body length about 8.3-10.4 times body height). Snout short (head length about 1.6 times upper jaw length), and round in cross section. Body densely covered with slender, bony scales whose tips are 3-5 cusped. Minute filelike teeth on both jaws and palatine. Lateral line curved above pectoral fin and straight to caudal portion. Head large (body length about 4.2-4.7 times head length). Eyes moderate in size, without ridge over the orbit. Dorsal profile straight from snout to insertion of first dorsal fin. Caudal fin deeply forked, both upper and lower lobes slightly narrow in width. Two lateral keels on either side of caudal peduncle. Pectoral fin somewhat low-situated (head length about 1.6-2.3 times pectoral length), with pointed tip. First dor-

sal fin starting above the posterior margin of preopercle, slightly higher than body height at its anterior end, down at the vicinity of 10th spine, again up to nearly the same height posteriorly and terminating just in front of insertion of second dorsal fin. Second dorsal fin and second anal fin small, nearly the same in size, and the latter situated anterior to the former. First anal fin somewhat small and crescent-shaped. Ventral fin longer than pectoral fin.

Fin membrane of first dorsal fin deep blue in color without spots. Other fins brown or dark brown. Basal part of first dorsal fin and second dorsal fin silvery white. Dorsal part of body deep blue, side somewhat brownish blue and belly silvery white.

Olfactory rosette radial in form, comprising 45-47 olfactory laminas. Gonad asymmetrical, Y-shaped; left lobe remarkably developed. Anus situated far anterior to insertion of first anal fin.

Variation in counts of spines and fin rays as provided in the literature are shown in Table 1.

Nakamura et al. (1968), who examined nine specimens from the northwestern Pacific, southeastern Pacific, and Indian Ocean, give the following ranges of fin ray counts: first dorsal spines, 47-50, second dorsal fin ray, 6-7; first anal spines, 12-15; second anal fin rays, 6-7; and pectoral fin rays, 18-19. These all fall within the ranges given in Table 1.

Merrett (1971) provides some morphometric relations for *T. angustirostris* (Table 2).

Geographic variation: Penrith (1964) suggests that there are geographic variations in pectoral fin length; the length of the pectoral fin forms a cline of increasing length eastward through the Indo-Pacific region. Penrith compared body proportions of a specimen taken in the Indian Ocean off South Africa with those of a Chilean specimen measured by Robins and de Sylva (1960) and noted that the values of these two specimens of *T. angustirostris,* taken at the extremes of the known range, agree very well except for the length of the pectoral fin. The ratio of the length of the pectoral fin to the body length is 9.8% for the South African fish of 1,456 mm and 15.0% for the Chilean fish of 1,822 mm, respectively. He adds to these the value of about 11% for Japanese fish, judged from the plates in Nakamura (1951) and Tanaka (1914). Penrith is of the opinion that although there is marked allometric growth of the pectoral fins in *T. pfluegeri* (Robins and de Sylva, 1963), it seems doubtful that there is any comparable allometric growth in *T. angustirostris*, because he sees no sign of allometric growth over a range of 1,470-1,857 mm (measured from tip of snout to fork) in the tables given by Royce (1957) for Hawaiian fish. The difference in size between the South African fish and Chilean fish is nearly comparable to the above range. This led Penrith to believe that the large difference in the ratios of the pectoral fin length to the body length between these two specimens may be due to geographic variation and not to the allometric growth of the pectoral fins. He also shows the following values for the pectoral fin length as expressed as a percentage of the first dorsal height: West Indian Ocean 76.6%, Hawaii (Royce, 1957) 87.4-100.4% with a mean of 94% and in the extreme east, off California 100.6% (Craig, 1958), and Chile 100.8% (Robins and de Sylva, 1960).

Merrett (1971) analyzed the morphometric data on *T. angustirostris* from the equatorial western Indian Ocean from the viewpoint of specific identity and compared the results with those from the Pacific Ocean given by Royce (1957). His comparison of the mean values of four characters, i.e., the length of the pelvic fin, the anterior height of first dorsal fin to the fork length, the anterior height of first anal fin to the anterior height of the first dorsal fin and the length of the 20th dorsal spine, shows that the values are in all cases smaller for the Indian Ocean fish. Merrett (1971) suggests that these probably reflect population differences in the species from the Pacific and Indian Oceans, since the same trend is apparent throughout. He gives the mean value of the pectoral fin length to body length of 11.6% for the six specimens he examined. According to Merrett, this tends to confirm the

Table 1.—Individual variation in counts of spines and fin rays of *Tetrapturus angustirostris*.

Spines and fin rays	Counts (upper figure) / Frequency (lower figure)								
Dorsal spines	44	45	46	47	48	49	50	51	52
			3	1	6	5	3	2	
Second dorsal fin rays		5	6	7	8	9			
			7	2					
Anal spines		11	12	13	14	15	16	17	
			2	1	3	1	1		
Second dorsal fin rays		5	6	7	8	9			
			3	6					
Pectoral fin rays		16	17	18	19	20	21		
			2	5	1				

Source: Tanaka, 1914; Robins and de Sylva, 1960; Ueyanagi, 1962; Watanabe and Ueyanagi, 1963; Merrett, 1971.

Table 2.—Various morphometric relations of *Tetrapturus angustirostris*.

Measurement or ratio of measurements	No.	Minimum	Maximum	Mean	Standard deviation
Pelvic fin length	5	28.2	34.7	30.0	2.5
Height DI / Fork L.	4	0.117	0.134	0.123	-
Height AI / Height DI	5	0.556	0.621	0.580	0.027
Height 20th ray of DI	6	14.1	16.9	15.0	0.9

hypothesis in the geographic variation proposed by Penrith (1964).

Morphological definition of subpopulations: The knowledge of subpopulations is insufficient to establish such a definition.

Description of morphological changes which occur during growth: Ueyanagi (1963b) reports the change in the length of the snout throughout growth as shown in Figure 2. The relation between snout length and body length shows a marked positive allometric growth until the larva attains a body length of 20-30 mm (measured from posterior margin of eye to end of central ray of caudal), then suddenly changes to a negative allometric growth throughout the young and immature stages. The morphological change in the snout during the early developmental stages is the most remarkable feature in this species. Generally in the billfishes, the dorsal fin is very large and high over its base during the larval stage but, except for its anterior lobe, decreases in height in the adult stage. In the shortbill spearfish, however, the dorsal fin is nearly the same height posteriorly even in the adult fish. From this, Ueyanagi (1963b) assumes that the form of the first dorsal fin of *T. angustirostris,* although unknown in the immature stage, changes little, and that the change is linear throught its life-span.

1.32 Cytomorphology

No information is available.

1.33 Protein specificity

No information is available.

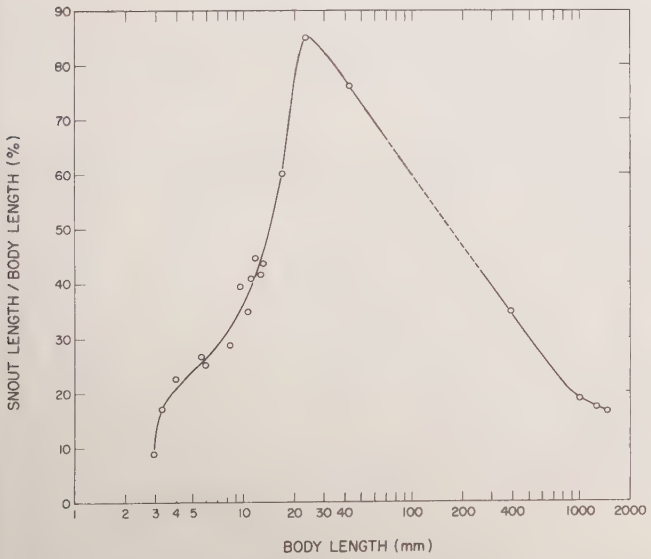

Figure 2.—Relation of snout length to body (eye-fork) length of *Tetrapturus angustirostris* during growth (Ueyanagi, 1963b).

2 DISTRIBUTION

2.1 Total Area

Geographical distribution: The occurrence of the shortbill spearfish is reported from Japan, Taiwan, California, Chile, South Africa, and very wide areas including the equatorial western, central, and eastern Pacific, the South Pacific, and the equatorial western Indian Ocean. This species is not reported to occur in the Atlantic Ocean and the Mediterranean Sea; howevern close relatives are present in these waters.

According to Nakamura (1937, 1949), this species is largely oceanic in distribution and does not enter coastal waters. It occurs in warm waters to the east of Taiwan (30-300 miles offshore). Near Japan, it is distributed in ocean waters south of lat. 35°N, but the density is not high.

Royce (1957) reports the sporadic occurrence of this species in the central Pacific Ocean between lat. 10°N and 10°S; information is based on longline fishing surveys conducted by POFI[3] vessels. In the Hawaiian fishery, according to Royce, the shortbill spearfish is one of the miscellaneous spearfishes that compose only a small fraction of the total billfish catch.

Koga (1959) states that in the South Pacific around the Fiji Islands there is a tendency of slightly increasing hooked rate toward the south between lat. 20° and 30°S.

Howard and Ueyanagi (1965) mention that this pelagic fish is dispersed throughout tropical and subtropical areas of the Pacific and density is always low except in the northwestern Pacific between lat. 15° and 30°N, where the density appears to increase from November through February.

Kume and Joseph (1969a, b) report the occurrence of the shortbill spearfish only in the high-seas area beyond about 600-700 miles from shore in the eastern tropical Pacific Ocean.

According to Merrett (1971), *T. angustirostris* is apparently more abundant during the southeast monsoon period, although this indication is due to high catch rates in only one monsoon period.

Within the area of the Japanese longline fishery which extends over the entire Pacific and Indian oceans between lat. 40°N and 50°S, this species is caught sporadically in areas roughly between lat. 30°N and 30°S. The catch report form used by the Japanese commercial longline fishery however, is such that catch data are not available for the shortbill spearfish and sailfish; these species are combined in a single column of the report. This pooling of the species in the catch record is related to the limitation in the number of columns on the punch card used for preparing the yearly statistics on the Japanese longline

[3]Pacific Oceanic Fishery Investigations; now the Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA.

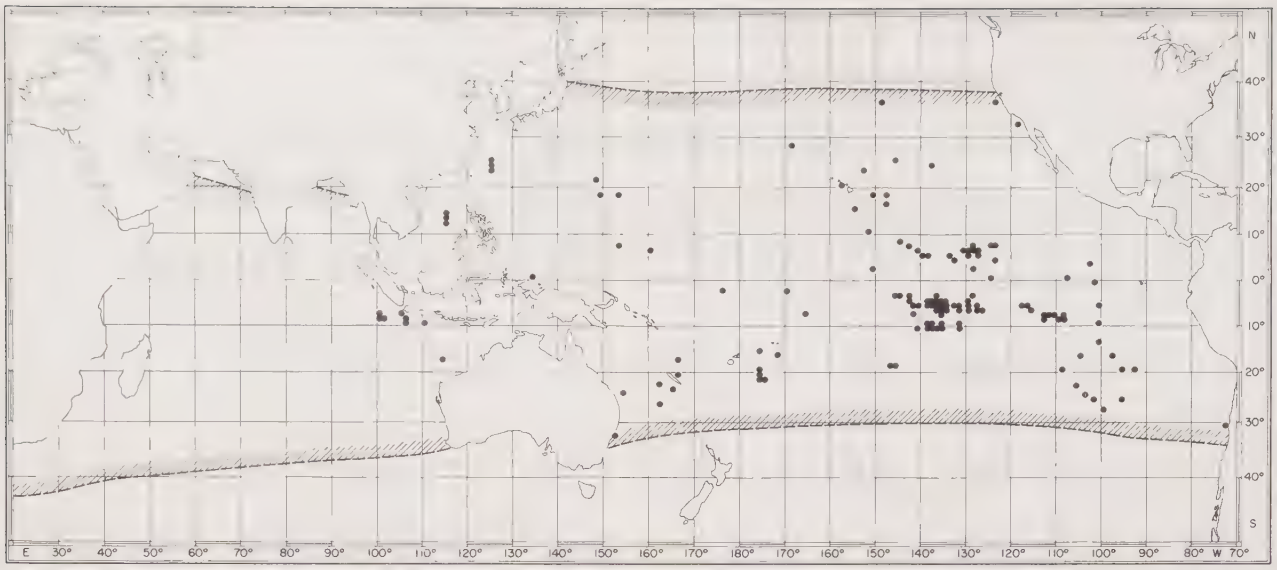

Figure 3.—Distribution of *Tetrapturus angustirostris*, occurrence by 1° square (Howard and Ueyanagi, 1965). Shaded lines for delimitation from combined shortbill spearfish and sailfish data from Japanese longline fishery in 1970.

fishery. This makes it impossible to separate these species and to delineate areas of their distribution in detail. The approximate geographical range in distribution of *T. angustirostris* is shown in Figure 3.

2.2 Differential Distribution

2.21 Spawn, larvae, and juveniles

Areas of occurrence and seasonal variation: Nakamura (1937) reports that the fish taken in waters adjacent to Taiwan in November released ripe eggs and assumed that spawning of *T. angustirostris* takes place in winter in warm offshore currents with surface water temperature of about 26°C. Fish with ripe ovaries are also reported to occur in the central Pacific Ocean by Royce (1957) and in the western Indian Ocean by Merrett (1971).

Ueyanagi (1962, 1963a, 1964) assumes from the occurrence of larvae and mature fish that spawning of this species is more active in winter than in summer, although fish are reported to spawn in the tropical and subtropical waters between lat. 25°N and 25°S. The distribution of larval fish from the western to the central Pacific Ocean as determined by Ueyanagi is in Figure 4. The larvae were collected from May through February or almost throughout the entire year. The sites of capture of larval fish are concentrated in an area between lat. 15° and 25°N in the western Pacific Ocean, reflecting the increased effort (tows) in this region. From the Indian Ocean, two larval specimens presumably identified as *T. angustirostris* were reported. They were collected at the Dana station 3855 southwest off Sumatra (Jones and Kumaran, 1964). Ueyanagi (1962) provides a comparison of the seasonal occurrence of larvae of the shortbill spearfish with that of the blue marlin in the western subtropical Pacific Ocean (Table 3).

For the western Indian Ocean, Merrett (1971) provides some data to indicate spawning of *T. angustirostris* and states that this species is more abundant during the southeast monsoon season, when the maturity of females is more advanced and the surface temperatures are at the lowest (mean 25.5°C). He mentions that this tends to confirm the suggestion by Ueyanagi (1964) that spawning activity is greater during the winter months.

2.22 Adult

Areas of occurrence and seasonal and annual variation: No information on annual variation is available. For seasonal variation, see 2.1.

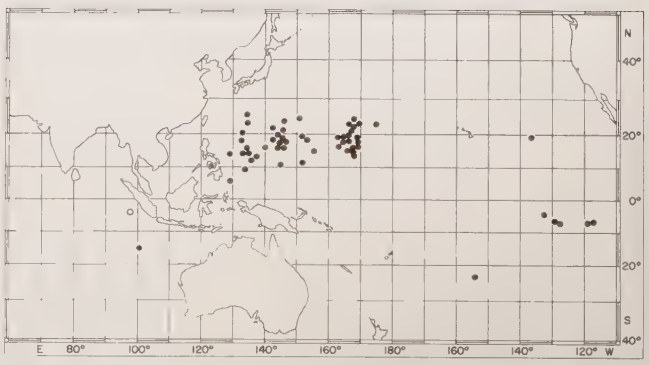

Figure 4.—Distribution of larval shortbill spearfish. Black dots from Ueyanagi, 1963a; open circle from Jones and Kumaran, 1964.

Table 3.—Larval occurrences of shortbill spearfish and blue marlin during winter and summer months in the western subtropical Pacific Ocean (lat. 15°-25°N) (Ueyanagi, 1962).

Season	No. of hauls	Species	Percent occurrence	Average no. per haul
Dec.-Feb.	69	Shortbill spearfish	14.5	0.25
		Blue marlin	4.4	0.16
May-Aug.	351	Shortbill spearfish	8	0.12
		Blue marlin	37.3	1.29

2.3 Determinants of Distribution Changes

To determine the vertical distribution of billfishes in the equatorial Indian Ocean, Merrett (1971) relates the percent catch rates of each species taken by the longline fishery to depth soundings and states that no *T. angustirostris* was caught in waters shallower than 500 fathoms. The highest catch rate for this species was obtained in the 501-1,000 fathom range and the catch rate decresed in deeper waters. Data are too sparse to be really significant, however.

2.4 Hybridization

2.41 Hybrids

No information is available.

2.42 Influence of natural hybridization in ecology and morphology

No information is available.

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

Hermaphroditism, heterosexuality, intersexuality: Heterosexual.

Nature and extent of hermaphroditism: No example of hermaphroditism of *T. angustirostris* has been reported thus far.

Sexual dimorphism: Despite many morphological studies, there is no report dealing with sexual dimorphism. Concerning the difference in size by sexes, Koga (1959) reports that larger fish are more frequently female than male in the size composition of longline catches made in the southeastern Pacific Ocean from September through November. Merrett (1971) states that no limitation of size by sex is observed in the longline catch from the equatorial western Indian Ocean.

3.12 Maturity

Size and weight at sexual maturity: The size of fish in running ripe condition reported thus far are as follows: a 1,524-mm specimen (measured from bill tip to origin of lateral keels on caudal peduncle) from the waters adjacent to Taiwan (Nakamura, 1937), a 1,638-mm specimen (measured from bill tip to caudal fork) from the central Pacific (Royce, 1957), and a 1,390-mm specimen (measured from center of orbit to shortest caudal ray) from the equatorial western Indian Ocean (Merrett, 1971). The specimen reported by Merrett was in the ovulation stage, the maturity stage was VI, and the fish weighed 18.6 kg (41 lb).

3.13 Mating

Monogamous, polygamous, promiscuous: Although the evidence is not certain, the billfishes seem to be promiscuous.

3.14 Fertilization

External.

3.15 Gonads

Merrett (1970) describes the ovulation for *T. angustirostris,* the final phase in the course of oogenesis which follows a point at which the eggs attain 750 μm in size. He states that immediately prior to this, the ovary becomes more vascular and the follicles, both theca externa and granulosa layers, then burst. On bursting, the released eggs swell by the uptake of liquid. The increase in size is a mean diameter of from 845 to 1,442 μm. Clearly, ovulation is not an all or none process, since barely half of the eggs in the ovary are estimated to be shed. Ovulation is observed to take place first centrally, and then radially outwards. His observations further suggest a continuous availability of spermatozoa in mature males by the differential maturation of the testicular lobules in conjunction with the possession of a muscular seminal vesicle. The male cycle appears dissimilar to the cycle in other teleosts while the female cycle is similar to other teleosts, as maturation is synchronous throughout the ovary.

Merrett (1971) estimated the mean fecundity of the Indian Ocean istiophorids and found that considerable variation occurs in the fecundity of *Istiophorus platypterus* and that such variation is apparently related to fish size. Although the relation

between egg number and fish size is not given, he provides the estimates of 6,200,000 and 2,100,000 eggs per spawning for two *T. angustirostris,* both 1,390 mm long (measured from center of orbit to shortest caudal ray). The latter estimate is made on unovulated eggs only.

3.16 Spawning

Nakamura (1938) assumes that spawning of the billfishes probably does not, as in other fishes, take place in large groups over a very short period of time, but probably is continuous over a long period and over a broad area of the sea. The reason for this, he states, is that it is known that in a single area fish with ripe eggs and those with unripe eggs are found mingled together over a period as long as 2 mo.

Nakamura (1943) mentions that spawning of the sailfish in a group takes place as individuals become ripe and that the male fish follows the female at the time of breeding.

3.17 Spawn

Merrett (1970) shows the frequency distribution of the diameters of eggs shed by this species, which ranges roughly from 1.30 to 1.60 mm with a mean of 1.442 mm.

According to Nakamura (1937, 1938), the eggs released from the ovary and preserved in alcohol are spherical and about 1 mm in diameter. The ovarian eggs, which are nearly mature (not fully ripe), are almost colorless and translucent, with slightly yellowish brown oil globules which unite until they grow into two fairly large globules. At this stage, the egg is nearly 0.8 mm in diameter.

3.2 Preadult Phase

3.21 Embryonic phase

No information is available.

3.22 Larvae phase

Morphology of this fish at the postlarval stage (Fig. 5) was studied based on about 90 specimens ranging in total length from 2.5 to 83 mm collected from the tropical and subtropical areas of the Pacific Ocean (Ueyanagi, 1962).

The ratio of the snout length to body length increases until the larva grows to about 50 mm in length. Among billfishes, *T. angustirostris* ranging from 20 to 50 mm in length has the largest snout relative to the body length.

The ratio of the head length to body length increases rapidly until about 7 mm in length, then increases less rapidly up to about 50 mm in length. The ratio of the head length is about 50% at 7 mm and about 60% at 50 mm in length. The ratio seems to continue to decrease gradually afterward. A wide space between the anus and the origin of the first anal fin, which is characteristic of this species, is already seen in larval fish larger than 20 mm long.

The pterotic and preopercular spines are formed at about 4 mm in length. As growth proceeds, this spination and the serration over the orbit and on the lower edge of the lower jaw are rapidly developed until they eventually undergo degeneration at about 20 mm in length. At this stage, the minute spiny scales begin to appear on the opercle and the surface of the body. In larvae greater than 70 mm, the spiny scales cover the whole surface of the body and the lateral line becomes evident. The palatine teeth appear at about 4 mm in length. There are 30 or more teeth on the upper jaw in fish about 20 mm in length. In larvae larger than 30 mm in length the teeth are beginning to degenerate.

The vertical fins are membraneous and not yet differentiated in larvae smaller than 4 mm. The ventral fins are formed in larvae over 4 mm long and at about 7 mm, the dorsal fin and the caudal fin are clearly differentiated. The fin rays and the hypural plate are also formed. At about 20 mm in length, the full complement of fin rays is reached. As development further advances, the dorsal fin becomes higher and saillike. The pectoral fins and the ventral fins become more elongate and the caudal fin is forked.

Melanophores are found on the body from the very early stage of development. At 2.4 mm in length, the melanophores appear on the head, the dorsal and the lateral sides of the trunk, and the dorsal wall of the body cavity. They are also visible along the urostyle, inside the isthmus, on the tip and the mid-part of the ventral side of the lower jaw, and on the branchiostegal membrane. The melanophores on the branchiostegal membrane is characteristic of *T. angustirostris* at the larval stage. As development proceeds, the pigmentation on the side of the body extends posteriorly and ventrally and covers the greater part of the caudal region at about 7 mm in length. The chromatophores appear on the dorsal fin in larvae over 15 mm, and at about 20 mm the whole side of the body is pigmented except for the tip of the hypural plate. A trace of the melanophores on the branchiostegal membrane is visible even in a specimen as large as 76 mm in length.

3.23 Adolescent phase

The following description is for a young specimen 514 mm in standard length (measured from bill tip to end of hypural plate) reported by Watanabe and Ueyanagi (1963).

The snout is elongate, being 26% as long as the body length (posterior margin of eye to end of central ray of caudal fin). The ratio of the upper jaw length to the lower jaw length is approximately 2:1. There is a dense growth of minute conical teeth on both upper and lower jaws, giving a filelike touch. The outer teeth are larger and found in rows and the inner teeth are coarsely implanted. Palatine teeth present. The gill

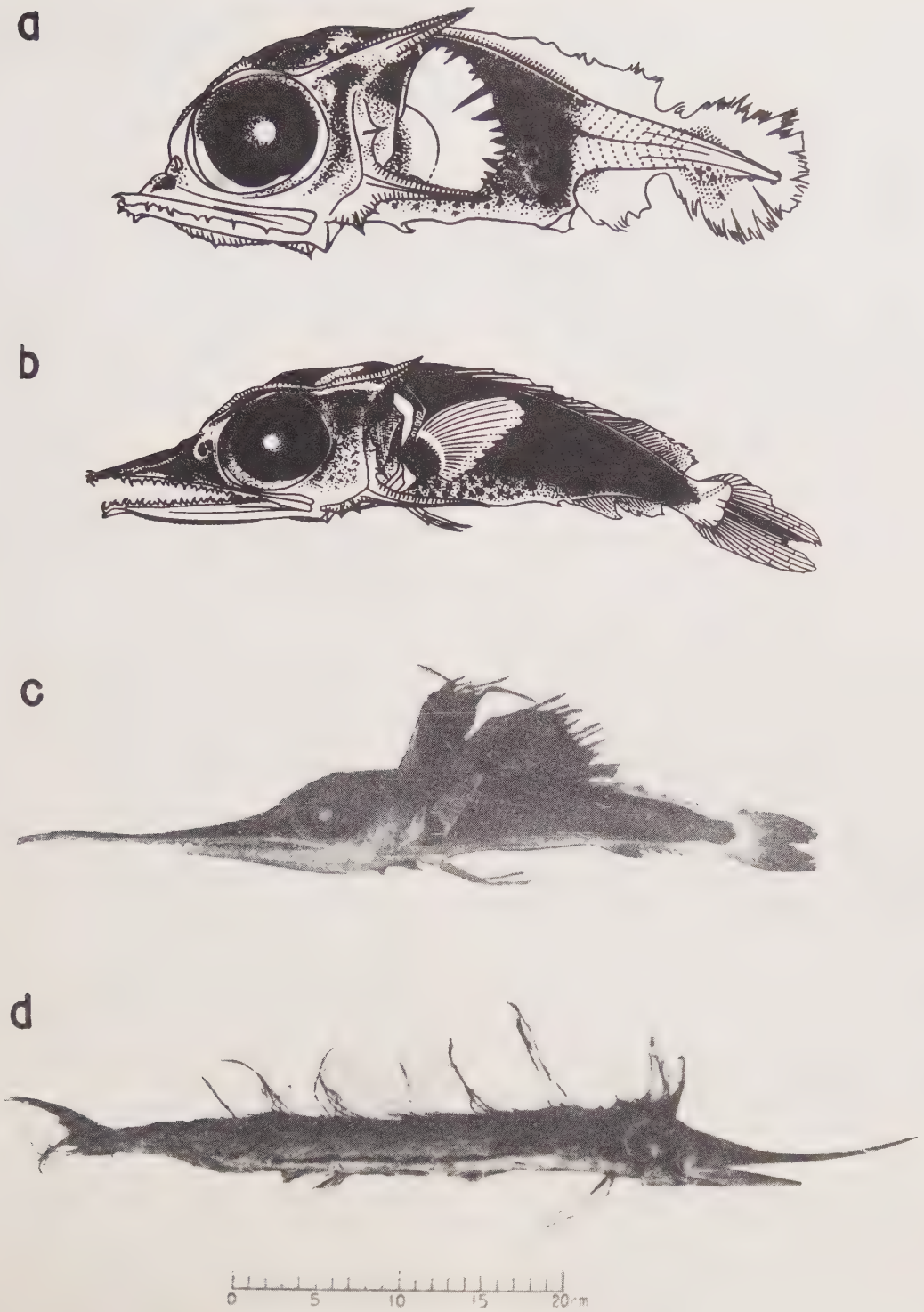

Figure 5.—Postlarval to young specimens of *Tetrapturus angustirostris*. a. 4.5-mm SL (Ueyanagi, 1963a), b. 13.0-mm SL (Ueyanagi, 1963a), c. 27.2-mm SL (Ueyanagi, 1963a), d. 514.0 SL (Watanabe and Ueyanagi, 1963). SL = standard length: from tip of snout to end of hypural bone.

rakers are not formed and, instead, there is a thick growth of villiform minute conical teeth on that part of the gill, giving a rough touch.

The height of the first dorsal fin is nearly the same throughout its entire base, but the anterior lobe is not yet formed and the fin rays in the central part are slightly higher compared with those of the adult. First and second dorsal fins are still continuous. Number of

dorsal spines and fin rays are 51 + 6. The grooves in which the first dorsal fin and the first anal fin are folded are formed throughout the entire base of each fin. The length of the pectoral fin nearly equals the height of the body. The ventral fins are considerably elongated, reaching the vicinity of the anus. The ventral groove in which the ventral fins are folded is developed. The spread of the caudal fin is not large compared with that of the adult. The space between the anus and the origin of the first anal fin is large, reaching about 26% of the length of the body cavity.

The body cavity is extremely long, extending to the first anal fin beyond the anus. The arrangement of the viscera is almost identical with that in the adult. Although completely immature, the left lobe of the gonad is longer than the right lobe, and elongated a little beyond a point at which the right lobe joins.

Scales cover the opercle and the whole surface of the body. They are cycloid with less exposed portion and appear to be at the early stage of development. The shape of the scales depends on the location of the scales on the body; those on the dorsal and the ventral parts are slender compared with those on the lateral part of the body. The lateral line is simple: it starts above the pectoral fin, being bent downward and running straight along the lateral median line from a point posterior to the pectoral fin to the caudal peduncle.

Sun (1960) reported on a juvenile specimen he identified as *T. angustirostris* from the Pacific Ocean. Ueyanagi (1962), however, believes this specimen to be the young form of *Eumakaira nigra* (= *Makaira mazara*), the Pacific blue marlin, in the light of features such as the remarkable shortness of the snout, the evenly high dorsal fin throughout its entire base and the form of the lateral line.

3.3 Adult Phase

3.31 Longevity

Nakamura (1938) states that fish over 20 kg are rare. Royce's (1957) largest specimen weighs 51 pounds (about 23 kg) and measures 1,859 mm from the bill tip to the caudal fork. According to the length composition of the South Pacific shortbill spearfish reported by Koga (1959), the largest fish is in the 151- to 155-cm (eye-fork length) class for males and in the 146- to 150-cm class for females. The largest specimen ever reported is a fish of 114 pounds (about 51.8 kg) given in Table 3 of Royce's paper (1957). This fish was landed at the Honolulu market in 1951.

3.32 Hardiness

Nothing has been reported on hardiness. Since billfishes are large and active dwellers of the ocean, their life will no doubt be very short in artificially confined environments. When hooked on longline gear, they often jump up above the sea surface, thrash violently and eventually entangle themselves with branch lines into almost exhaustion before they are landed.

3.33 Competitors

Billfishes, together with tunas, constitute a group of apex predators in tropical and subtropical waters. They appear to compete with one another in feeding, since previous reports (Suda, 1953; Yabuta, 1953; Watanabe, 1960; Koga, 1967; Mori, 1967[4]) indicate that they have no marked food preference and there is no significant differences in their stomach contents. Sharks or other kinds of fishes such as dolphins, barracudas, Spanish mackerels also probably compete in feeding with tunas and billfishes.

3.34 Predators

When hooked on longline gear, it is well known that tunas and billfishes are frequently attacked by sharks or perhaps killer whales. Although information is lacking, sharks and killer whales probably prey on tunas and billfishes.

3.35 Parasites, diseases, injuries, and abnormalities

No information is available.

3.4 Nutrition and Growth

3.41 Feeding

Information is scarce on diel feeding habits, manner, frequency, and variation of feeding habits in relation to environmental and physiological conditions. Yabuta (1953) notes that different kinds of food organisms tend to appear in stomachs of tunas and billfishes including *T. angustirostris* as the season changes. It has not been determined, however, whether this difference is due to the difference in fish species from which stomachs were collected or to other reasons.

3.42 Food

Types eaten and their relative importance in the diet: The stomach contents of billfishes comprise a very large variety of crustacea, mollusca, tunicata, pisces, and coelenterata. Of the food items, squid and fishes are the most important in frequency and number (Suda, 1953; Yabuta, 1953; Watanabe, 1960; Koga, 1967; Mori, 1967 (see footnote 4); Koga, Imanishi, and Tawara, 1972). These reports agree in that the billfishes, as do tunas, feed on commonly pres-

[4]Mori, K. 1967. Interim report on the investigation of stomach contents of billfishes. Report presented at Tuna Fisheries Research Meeting, 1966, 5 p.

ent and easily available organisms in their habitats. Watanabe (1960) stated that there is no significant difference between the stomach contents of tunas and billfishes except that billfishes feed more frequently on juvenile tunas and billfishes than tunas do. The forage organisms which are the most common in the stomachs of billfishes in the North Pacific Ocean are squid and fishes of the Lepidotidae, Alepisauridae, Acinaceidae, and Katsuwonidae.

Koga et al. (1972) examined the stomach contents of the shortbill spearfish in the central South Pacific Ocean and pointed out that the number of species of fish eaten by this species is limited compared with the striped and blue marlins, although the food of this species is almost identical with the other marlins with respect to the cephalopods and crustaceans. They noted that the members of the Myctophidae, Triacanthidae, and *Polyipnus* which are considered to be deepwater dwellers are lacking in the stomachs of the shortbill spearfish. These authors assume from this that the shortbill spearfish swim in a shallower layer of water than do the striped and blue marlins.

Volume of food eaten during a given feeding period: Information is lacking on the absolute volume of food eaten by this species. Koga et al. (1972) examined the relative volume of stomach contents of tunas and billfishes by classifying it into five categories and mentioned that the shortbill spearfish and yellowfin tuna more often have stomachs filled with food than the albacore, striped marlin, and blue marlin do. They also stated that the shortbill spearfish and albacore tend to eat smaller food items than do the other tunas and billfishes.

3.43 Growth rate

Relative and absolute growth pattern and rates: The annual growth rate has been estimated for the Atlantic sailfish (de Sylva, 1957), the western Pacific sailfish and striped marlin (Koto and Kodama, 1962a; Koto, 1963) and the black marlin in the South China Sea (Koto and Kodama, 1962b). Age determination using hard tissues such as scales, otoliths, and contra are difficult to apply to the billfishes (Koto and Kodama, 1962a). Information on the absolute growth is lacking for the shortbill spearfish. (For relative growth, see 1.31.)

3.44 Metabolism

No information is available.

3.5 Behavior

3.51 Migration and local movement

Data available thus far are too limited to consider the movement of this species.

3.52 Schooling

Composition of stocks by size, age, and sex: See 4.13.

Mixing between schools: Howard and Ueyanagi (1965) mention that the two areas of greatest density of the Pacific shortbill spearfish appear to correspond with the overlapping borders of distribution of striped and blue marlins, and speculate whether, if more data were available, the same might be found for all such areas of overlap between the distribution of striped and blue marlins. For schooling habit, see 3.16

3.53 Response to stimuli

No information is available. For response when hooked in the longline gear, see 3.32.

4 POPULATION

4.1 Structure

4.11 Sex ratio

According to Nakamura (1944), the sex ratio of the shortbill spearfish and sailfish is nearly 1:1 during the spawning season in waters adjacent to Taiwan. For the swordfish and the striped, blue, and black marlins, the size difference with sex and the seasonal change in sex ratio are noted (Nakamura, 1944; Nakamura, Yabuta, and Ueyanagi, 1953; Ueyanagi, 1953). Koga (1959) states that size difference with sex is also evident for the shortbill spearfish in the South Pacific; the female is larger in average length than the male. The catch data collected during 1966-70, however, suggest that the difference in size between the sexes for this species is not so definite as first expected (Koga et al., 1972). The sex ratio from September through November in the South Pacific, according to Koga's data, is 1:1.54 (M:F). The preponderance of females in the catches of this species is also noted in the equatorial western Indian Ocean, although the longline catches are quite few (Merrett, 1971).

4.12 Age composition

No information is available on age.

4.13 Size composition

Size composition of the shortbill spearfish from the Pacific Ocean is reported by various authors (Royce, 1957; Koga, 1959, 1967; Kume and Joseph, 1969b; Strasburg, 1970; Koga et al., 1972). The size composition of fish from the Indian Ocean is given by Merrett (1971). Although data on size compositions reported thus far are limited in number and fragmental seasonally, there appears to be a difference in size according to localities in the Pacific Ocean. As shown in

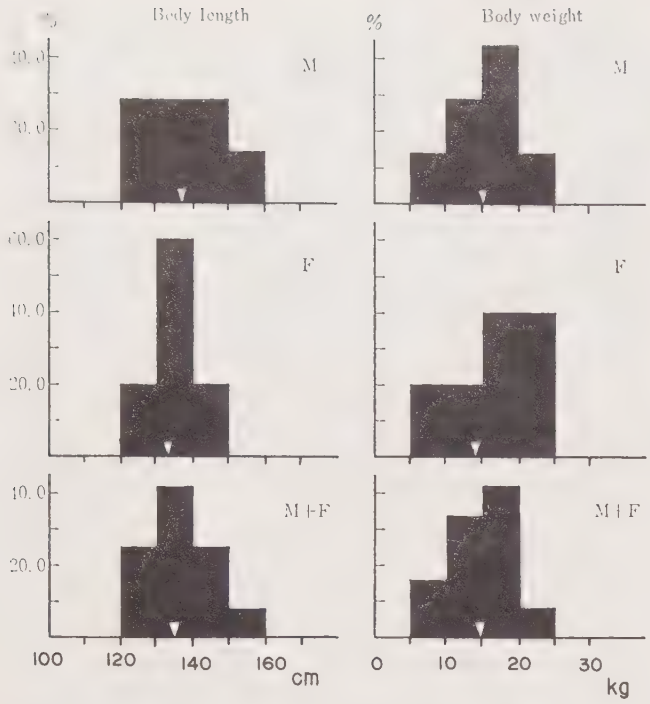

Figure 6.—Body (eye-fork) length and weight compositions of shortbill spearfish caught by longline fishery in the central South Pacific Ocean (lat. 16°-28°S, long. 166°E-174°W), November-December 1969. M = male; F = female; white triangle = average (Koga, Imanishi, and Tawara, 1972).

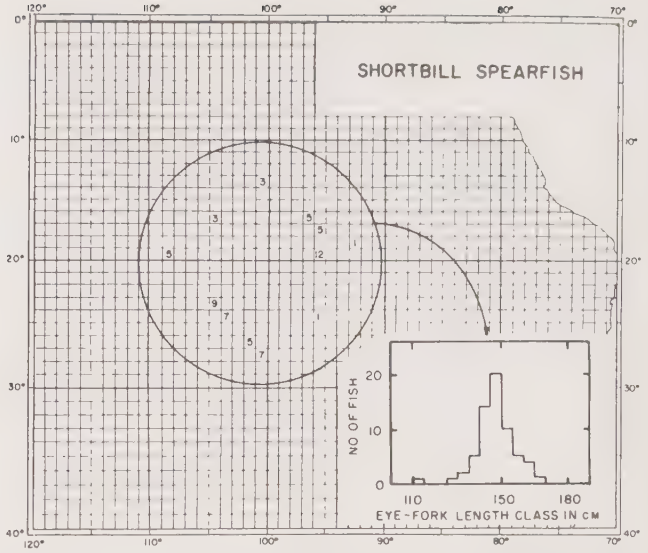

Figure 7.—Size composition of 63 shortbill spearfish captured in the eastern Pacific Ocean during 1963 and 1964 by the RV *Shoyo Maru*. Number and location of fish measured are shown by 1° areas. (From Kume and Joseph, 1969b).

Figures 6 and 7, the average length of fish caught by the longline fishery is about 135 cm in the central South Pacific and about 150 cm in the eastern Pacific, suggesting an increasing tendency in size toward the east.

Kume and Joseph (1969b) report the weight-length relation for the shortbill spearfish taken in the Pacific Ocean east of long. 130°W. To describe the relationship, they use the equation $\log_{10} Y = \log_{10} a + \log_{10} X$ and fitted the data by the least squares method, where Y is the weight in kilograms and X the eye-fork length in centimeters. The data employed are of two types, 1) gilled and gutted and 2) whole, both from the Japanese longline fishery. The regression coefficient (b) and the Y intercept ($\log_{10} a$) they obtained are 3.9195 and -7.2239 for the gilled and gutted, and 3.7242 and -6.8146 for the whole, respectively. The number of fish and the size range of specimens examined are 89 fish and 102.4-167.0 cm long for the gilled and gutted, and 19 fish and 128.0-156.0 cm for the whole, respectively. Koga et al. (1972) use the same weight-length relation and obtain the value of 4.5926 as the regression coefficient for the South Pacific shortbill spearfish.

4.2 Abundance and Density (of Population)

4.21 Average abundance

The population size is not yet estimated.

4.22 Changes in abundance

Because of the inadequacy of the catch statistics of this species (see 2.1), the changes in abundance cannot be considered at present.

4.23 Average density

Annual mean density for any given area or any given year has not been calculated.

4.24 Changes in density

The apparent relative abundance is low throughout areas of the longline fishery compared with the striped and blue marlin. In 1958, it ranged from 0.16 fish to 0.3 fish per 100 hooks depending on areas of the fishery in the South Pacific between lat. 20° and 30°S and between long. 170°E and 170°W (Koga, 1959). Concerning variation with depth, there is an indication in the equatorial western Indian Ocean that the highest catch rate for this species was in the 501-1,000 fathoms range (Merrett, 1971; see 2.3). Merrett indicates the value of approximately 0.03 fish per 100 hooks in this depth range.

4.3 Natality and Recruitment

4.31 Reproduction rates

No information is available.

4.32 Factors affecting reproduction

No information is available, except for the general recognition that the transportation, dispersion, and mortality of the larval fish population may be greatly

affected by physical and biological factors such as, for example, the ocean currents, water temperature, food supply, and predation.

4.33 Recruitment

No information is available.

4.4 Mortality and Morbidity

No information is available.

4.5 Dynamics of Population (as a Whole)

Knowledge is limited. See 4.24 for information on apparent abundance.

4.6 The Population in the Community and the Ecosystem

Knowledge is very limited and no particular information is available.

5 EXPLOITATION

5.1 Fishing Equipment

5.11 Gear

The tuna longline fishery is essentially responsible for all of the commercial shortbill spearfish catch from the Indo-Pacific areas. The longline gear has been developed to catch tunas, billfishes, and sharks that are more or less sparsely distributed in a depth range roughly from 50 to 150 m. The form of the gear set in the water is as shown in Figure 8.

A single unit of gear consists of the main line, a number of branch lines, each with a hook, the float line and the buoy. The depth at which the hook hangs from the main line can be adjusted by the length of the float line. The construction of the gear differs depending on the species of fish sought, the conditions of fishing grounds and the efficiency of fishing vessels. When aiming mostly at the albacore or a species of salmon shark, as seen in Table 4, the gear ordinarily used by the fishermen has relatively short branch lines with short spacing between them. In such a construction the branch lines in a single unit of gear tend to increase in number. With increasing size of the species of fish sought such as yellowfin and bigeye tunas, the length of the branch lines and the spacing between them tend to increase and the number of the branch lines in a single unit tends to decrease. This appears to come from the fishermen's experience in improving fishing efficiency by considering the density of schools of the fish sought, and in preventing the gear from tangling while it is in the water or is being retrieved. The relation between the length of the branch lines and the spacing between them is given in Figure 9.

The length of the main line tends to increase according to the size of the vessels and the power of a longline hauler rather than to the size of fish sought.

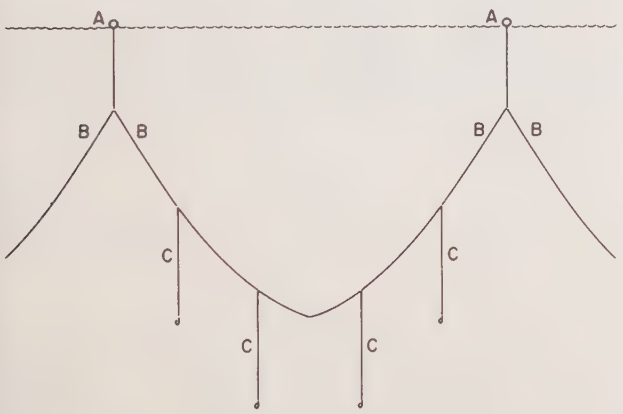

Figure 8.—An example of the longline gear: A, buoy; B, main line; C, branch line. (Katsuo-Maguro Nenkan, 1969).

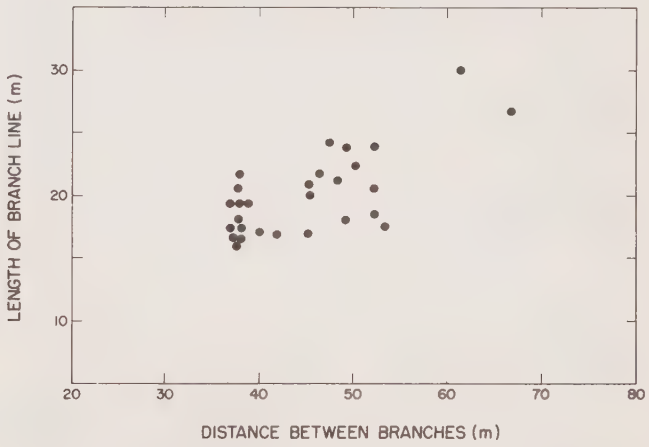

Figure 9.—Relation between length of branch line and distance between branches (Katsuo-Maguro Nenkan, 1969).

Table 4.—Longline gear construction by the species of fish sought (Katsuo-Maguro Nenkan, 1969).

Fish sought	No. of branch lines	Distance between branches	Length of branch lines	Hook size	Length of main line (single unit)
		m	*m*		*m*
Albacore, salmon shark	6-9	20-40	12-18	#34-36	140-360
Yellowfin tuna	5-6	40-50	20-22	#36-38	240-360
Bigeye tuna	4-5	50-60	22-25	#37-38	250-360

The adjustment of fishing depth is achieved by slackening the main line while setting the gear as well as by adjusting the length of the float line. With the float line of 20-40 m and the slackening rate of the main line of 20-50%, the adjusted depth of hooks appears to range from 60 to 150 m (Katsuo-Maguro Nenkan, 1969).

Recently, much effort has been directed at developing labor-saving devices and devices for improving fishing efficiency in the Japanese longline fishery. This effort has led to the gradual improvement of devices within the actual fishery and the development of essentially different methods which may represent breakthroughs in fishing technology. The former is represented by the introduction of two similar devices of longlining, the reel-type and the tub-type gear with improvement in related equipment such as the gear-transporting conveyor and guide stand system, and the latter, for example, by the development of the so-called wire fishing or automatic snapping (Katsuo-Maguro Nenkan, 1969).

5.12 Boats

Most Japanese tuna longline vessels which have recently been built are in the 240-ton class. Table 5 gives the specification of larger vessels in the 340-ton class. Recently, many of these vessels have been equipped with refrigerators capable of preserving the catch at very low temperatures of 40° or -45°C.

5.2 Fishing Area

See 2.1, 2.21, 2.22, 2.3.

5.3 Fishing Season

See 2.1, 2.21, 2.22, 2.3.

5.4 Fishing Operations and Results

5.41 Effort and intensity

Fishing effort for billfishes can practically be expressed by the fleet size of the tuna longline fishery or, in more detail, by the number of hooks used. For the shortbill spearfish, however, this has never been estimated. To assess the fishing effort exerted on a given species of fish, information is first required on the catches of that species and its inherent geographical pattern of density in addition to the crude total effort. In this sense, the improvement of data format from commercial vessels for preparing the catch statistics

Table 5.—Specification of 340-ton class tuna longline vessels.

Items	Vessel 1	Vessel 2	Vessel 3	Vessel 4
Gross ton T	339.79	338.87	338.77	238.68
L (m)	43.74	43.00	43.00	42.80
B (m)	7.80	7.80	7.70	8.00
D (m)	3.80	3.80	3.75	3.80
L/B, L/D, B/D	5.61, 11.51, 2.05	5.51, 11.31, 2.05	5.58, 11.46, 2.05	5.35, 11.26, 2.11
LBD, T/LBD	1,297, 0.26	1,274, 0.27	1,241, 0.27	1,301, 0.26
Fish hold (m^3)	440.4	400.2	345.6	402.9
Freezing room (m^3)	72.2	72.0	87.5	73.5
Freezing capacity/day (t)	13.0	10.0	11.7	7.0
Fuel oil tank (m^3)	230.0	184.9	203.5	200.8
Fresh water tank (m^3)	28.0	21.5	22.3	24.4
Main engine:				
Model	4.D.S.	4.D.S.	4.D.S.	4.D.S.
Rating horse power (PS)	750	750	800	800
Rating revolutions	320	320	330	330
Cylinder (mm)	6 × 370 × 520	6 × 370 × 520	6 × 350 × 500	6 × 350 × 500
Propeller	4 × 1,980 × 1,250	4 × 2,060 × 1,195	4 × 2,000 × 1,240	4 × 2,050 × 1,175
Auxiliary engine:				
Model number	4.D×2	4.D×2	4.D×2	4.D×2
Rating horse power	130	130	130	125
Rating revolutions	720	720	720	750
Generator	100KVA × 230KVA × 1	100KVA × 2	100KVA × 2 30KVA × 1	100KVA × 2 25KVA × 1
Refrigerator	NH_3 26.7R.T × 3	NH_3 27.5R.T × 3	NH_3 44RT × 1 40R.T × 1	NH_3 26.7R.T × 3
Wirless telegram	200W	250W	250W	250W
Direction finder	1	1	1	1
Fish finder	1	1	1	1
Radar	1	1	1	1
Loran	1	1	1	1
Gyro	1	1	1	1

in Japan must be made for the shortbill spearfish (see 2.1).

5.42 Selectivity

The longline gear takes fish distributed at a depth range roughly from 50 to 150 m, while the pole-and-line and the purse seine gears catch those living near the surface. For tunas, this means that the longline fishery exploits larger fish than does the surface fishery.

Concerning the effect of selective properties of the longline gear on growth studies, Suzuki (1971) set forth the following hypothesis and examined the possibility of gear selectivity in connection with Lee's phenomenon: If a fishery exploits fish within a certain size range, the fishery tends to catch larger individuals out of the young fish group whose size is near the lower limit of the selective range of the gear and smaller ones out of the old fish group whose size is near the upper limit. The catches, therefore, tend to represent larger members for the young group and smaller ones for the old group compared with fish actually distributed in the sea. Applying this to the longline fishery, samples from the catch would result in erroneously larger estimates of growth coefficient and smaller estimates of asymptotic length.

6 PROTECTION AND MANAGEMENT

Protection and management are the most important and urgent issues we now face in the world tuna resources. Presently, little attention is paid to the shortbill spearfish stock(s) because it is less important in the commercial and sport fisheries. This, however, does not appear to fix the relative value of the shortbill spearfish in the future management of the fishery.

7 POND FISH CULTURE

Not applicable.

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Synopsis of the Biology of the White Marlin, *Tetrapturus albidus* Poey (1861)[1]

F. J. MATHER III, H. L. CLARK, and J. M. MASON, JR.[2]

1 IDENTITY

1.1 Nomenclature

1.11 Valid name

Tetrapturus albidus Poey, 1861 (Fig. 1).

Poey, Felipe. July 1861 Memorias sobre la historia natural de la Isla de Cuba. Habana, vol. 2, 442 p. (ref. p. 237-243, 258-260; pl. 15, fig. 1, 3; pl. 16, figs. 2-13; pl. 17, figs. 1-11, 21, 26).

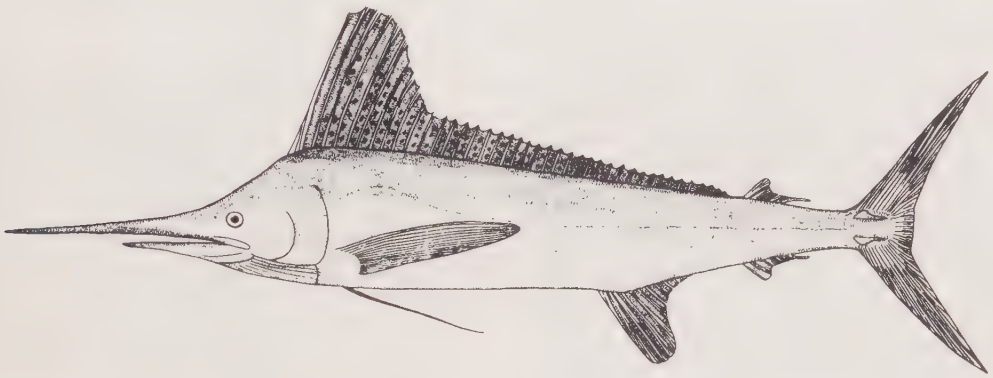

Figure 1.—White marlin, *Tetrapturus albidus* Poey, 1860. (From Nakamura et al., 1968, Fig. 19.)

1.12 Objective synonymy

No type specimen exists, therefore there are no objective synonyms.

1.2 Taxonomy

1.21 Affinities

Suprageneric

Phylum Chordata
Subphylum Vertebrata
Superclass Gnathostomata
Class Osteichthyes
Subclass Actinopterygii
Order Perciformes
Suborder Xiphioidei
Family Istiophoridae

Generic

Genus *Tetrapturus* Rafinesque 1810.

Rafinesque, C. S. 1810, "Caratteri di alcuni nuovi generi e nuove specie de animale e piante della Sicilia." Palermo, 105 p., 20 pls. (ref. p. 54-55, pl. 1, Fig. 1). Type species; *Tetrapurus belone* Rafinesque, 1810.

We follow the generic concept of C. R. Robins and D. P. de Sylva, 1960, "Description and relationships of the longbill spearfish, *Tetrapturus belone*, based on western North Atlantic specimens," Bulletin of Marine Science of the Gulf and Caribbean, 10:383-413, 5 figs. (ref. mat. p. 383, 404-406, Fig. 5), and 1963, "A new western Atlantic spearfish, *Tetrapturus pfluegeri*, with a redescription of the Mediterranean spearfish *Tetrapturus belone*," Bulletin of Marine Science of the Gulf and Caribbean, 13:84-122, 5 figs. (ref. mat. p. 101-102).

The following are transcribed from Robins and de Sylva (1960), page 385:

[1] Contribution No. 3110 from the Woods Hole Oceanographic Institution, Woods Hole, MA 02543.

[2] Woods Hole Oceanographic Institution, Woods Hole, MA 02543.

Tetrapturus Rafinesque

Tetrapturus Rafinesque, 1810: 54-55 (*T. belone,* type species by monotypy).

Skeponopodus Nardo, 1832: 99 (*nomen nudum*); 1833: 415-419 (*S. typus*, [= *T. belone* Rafinesque], type species by virtue of the name *typus*).

Tetrapterurus Bonaparte, 1841: 19 (emended spelling).

Tetrapterus Agassiz, 1843: 7, 89-92, table E (emended spelling).

Tetraplurus Vérany, 1847: 492-494 (misprint for *Tetrapturus?*).

Scheponopodus Canestrini, 1872: 112 (emended spelling).

Tetraperus Radcliffe, 1926: 112 (misprint for *Tetrapturus*).

Marlina Grey, 1928: 47 (*Tetrapturus mitsukurii* Jordan and Snyder,] = *T. Audax* Philippi], type species by monotypy; the use of *Marlina* at the generic level is probably a slip).

Kajikia Hirasaka and Nakamura, 1947: 13-14 (*Kajikia formosana*,] = *Tetrapturus audax* Philippi], type species by monotypy).

Pseudohistiophorus de Buen, 1950: 171 (*Tetrapturus illingworthi* Jordan and Everymann] = *T. angustirostris* Tanaka], type species by original designation).

Lamontella Smith, 1956: 32 (*Tetrapturus albida* [sic] Poey, type species by original designation and monotypy).

and p. 402-404:

Relationships.—The limits of the genus *Tetrapturus* are ill-defined in current literature, perhaps due in part to the prior lack of information about the type species *belone*. Nakamura (1949 and English translation, 1952) divided the Istiophoridae into two subfamilies Tetrapturinae and "Marlinae" (=Makairinae). Other workers either overlooked or failed to follow this lead. *Makaira*, as currently constituted, bridges this break and is unnatural; its species are in part assigned to *Tetrapturus* below. We agree with the basic dichotomy suggested by Nakamura although the divisions need not be designated subfamilies. To the definitions of Nakamura (1938, 1949) we add the character of negative allometry of the bill in the "Tetrapturinae" versus positive allometry in the "Makairinae." Also the "Tetrapturinae" are small species, generally much less than 300 lbs. while the two members of the "Makairinae" reach about 2000 lbs. The world-record "striped marlin," a 692 lb. individual taken off Balboa, California, August 18, 1931, is a blue marlin, *M. nigricans*.

LaMonte (1955:325) separated *Tetrapturus* from *Makaira* largely on the basis of the length of the pectoral fin. As already noted, the pectoral fin shows marked allometry in the spearfish. Also, *Tetrapturus*, as here constituted, includes one species (*angustirostris*) that apparently has a short pectoral and several species with very long pectorals; therefore this feature will not aid generic definition. . . .

The relationships of *Tetrapturus* are with *Istiophorus* rather than *Makaira* as here restricted. Our concept of the phylogeny of the Istiophoridae is diagrammed in Figure 5. The species of *Istiophorus* are poorly known but it already appears that few species are represented. The only characters separating *Istiophorus* from *Tetrapturus* are the form of the dorsal fin and the nature of the pelvic fins. Even the character of the dorsal fin breaks down for when all species are considered *T. belone* and *T. angustirostris* are somewhat intermediate. Moreover the young of all included species have high dorsal fins, but this feature is extreme in *Istiophorus* . The structure of the pelvic fin has been insufficently investigated. We choose to retain *Istiophorus* and *Tetrapturus* as genera but a case could be made for ranking them as subgenera.

Figure 5 of Robins and de Sylva (1960) is reproduced here as Figure 2.

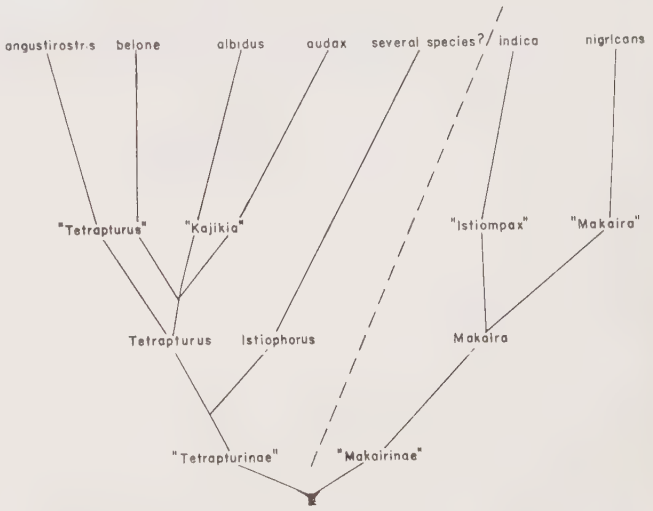

Figure 2.—Phylogenetic relationships of fishes of the family Istiophoridae. Names in quotations are not employed by the present writers. (From Robins and de Sylva, 1960, Fig. 5 and caption.)

After examining Mediterranean material, Robins and de Sylva (1963) assigned the western Atlantic specimens, which they had described as *T. belone* Rafinesque in their 1961 paper to a new species, *T. pfluegeri* Robins and de Sylva, and redescribed *T. belone* Rafinesque on the basis of the Mediterranean material which they had examined. Further statements on the species of *Tetrapturus* and the relationship of this genus to the genera *Istiophorus* and *Makaira* transcribed from Robins and de Sylva, 1963, p. 100-102, follow:

> . . . Aside from the 12 caudal and 12 precaudal vertebrae that all share, the important characters of the species of *Tetrapturus* involve the number of dorsal spines, shape and pigmentation of the spinous dorsal fin, height and shape of the anal fin, length of the pectoral fin in the adult, position of anus, shape of dorsal profile from the base of the bill to the spinous dorsal, and bill length . . . .
>
> In their delineation of *Tetrapturus* and placement of it with *Istiophorus* on one branch of the istiophorid dendrogram, Robins and de Sylva (1961: 402) referred to Nakamura (1949). Nakamura (1938), though recording the vertebral differences, neither defined nor suggested such a subdivision of the Istiophoridae. This dichotomy actually dates from the work of Hirasaka and Nakamura (1947). These subdivisions are natural, but need not be accorded subfamily rank, although some ichthyologists will choose to do so. It was not our intent in our earlier paper to suggest such ranking for in small families like the Istiophoridae subfamilies are unnecessary and serve no important purpose. These subdivisions are defined as follows (in each instance the first condition applies to that containing *Tetrapturus* and *Istiophorus*, the second to that containing *Makaira*.) 1. Precaudal vertebrae 12, caudal vertebrae 12 *vs.* precaudal

vertebrae 11, caudal vertebrae 13 (these vertebral differentiations into precaudal and caudal elements are clear [see Nakamura, 1938 and Pls. 4-5 of 1955 translation] and no variant is known for any species). 2. The bill is proportionately longer in juveniles than in adults *vs.* the opposite condition (this is independent of the ultimate length of the bill of any species). 3. Size relatively small, less than 200 lbs., except for *T. audax* which sometimes exceeds 400 lbs. (as previously noted [Robins and de Sylva, 1961: 403] the world-record 692-lb. striped marlin is misidentified and is really *Makaira nigricans*, the blue marlin) *vs.* size very large, both species approaching 2000 lbs. 4. Anterior lobe of dorsal fin high, equal to or exceeding the body depth at this point *vs.* anterior lobe of dorsal low, less than the body depth at this point.

Robins and de Sylva (1960, 1963) assign, as a result of their work, five distinct species to the genus *Tetrapturus—T. angustirostris, T. belone, T. pfluegeri, T. albidus,* and *T. audax*—with a transition running from *Tetrapturus* of the *angustirostris* type to that of the *audax* type consecutively. Specific differences are discussed in Robins and de Sylva, 1963, p. 100-102, Tables 6 and 7.

Specific

Type specimen: No type specimen exists.

Type locality: North coast of Cuba (Poey, 1861).

Diagnosis: Fishes of the family Istiophoridae are distinguished from all others by the extension of the upper jaw into a short pointed spear of nearly round cross section, and a pair of small cartilaginous keels on either side of the base of the caudal fin. In the most closely related family, Xiphiidae, the upper jaw is extended into a long sword, much flattened vertically and sharp at the horizontal edges; there is a single large fleshy keel on either side of the base of the caudal fin, and the ventral fins, present in the Istiophoridae, are lacking.

In its adult form, *T. albidus* is easily distinguished from the other Istiophoridae. It differs from the *Makaira* species in: vertebral count—12 + 12 vs. 11 + 13; maximum height of first dorsal fin—more than depth of body vs. less than depth of body; body ehape—slender (depth less than length of pectoral fin) vs. stout (depth usually greater than length of pectoral fin); lateral line—distinct, single vs. obscure, single or complex; lobes of first dorsal and first anal fins—strongly rounded at extremities vs. pointed at extremities; spear—long and slender vs. short and stout; size—small (less than 100 kg) vs. large (approaching 1,000 kg). The above characters are from Nakamura (1949), LaMonte (1955), and Robins and de Sylva (1960, 1963). *Tetrapturus albidus* is easily distinguished from *Istiophorus* by the size and shape of the first dorsal fins. The first dorsal of *T. albidus* is distinctly peaked anteriorly, and its height tapers posteriorly. Its maximum height is less than twice the body depth. The dorsal fin of *Istiophorus* is highest in the middle portion of its length, and its maximum height is much more than twice the body depth.

Tetrapturus albidus may be distinguished from *T. belone, T. pfluegeri,* and *T. angustirostris* by the strongly rounded lobes of its first dorsal and first anal fins, the shape of its dorsal fin, and the location of its anus. The anterior distal extremities of the first dorsal and first anal fins of the latter three species are pointed rather than rounded; their first dorsal fins are not as distinctly peaked anteriorly, and are higher in their middle portion than that of *T. albidus,* making the height of the fin more nearly uniform. The anus of *T. albidus* is near (4.8-5.8% of body length) the anal fin origin, but in the other three species, it is from 6.3 to 11% of the body length from the anal fin origin. The spear of *T. albidus* (26-35% of body length) is longer than that of *T. pfluegeri* (19-25% of body length) and much longer than those of *T. belone* and *T. angustirostris.* These data are from Robins and de Sylva (1963).

Tetrapturus audax is the species most similar in external appearance to *T. albidus.* Although the former is an Indo-Pacific species, the ranges of the two overlap at least off South Africa (Talbot and Penrith, 1962). The main difference noted by LaMonte (1955) was the lateral line—conspicuous in *T. albidus,* and invisible or very inconspicuous in *T. audax.* Robins and de Sylva (1960) separate these species on the basis of the strongly rounded tips of the spinous dorsal, anal, and pectoral fins, and the red flesh of *T. albidus,* and the pointed tips of these fins, and pale flesh, of *T. audax*. The experience of the senior author has been that roundedness vs. pointedness of pectoral fins is a very unreliable character in separating scombroid fishes and that the tip of the spinous dorsal of *T. audax* is not always sharply pointed. The best character in separating these species probably is the shape of the anal fin. In fact, this character easily separates *T. albidus* from all the other Istiophoridae.

The diagnosis of larval and juvenile *T. albidus* is little known. We can only reproduce the key of de Sylva (1963) for young specimens (50-500 mm in length) of the istiophorid species known in the western Atlantic.

A provisional key is presented to assist identification of young specimens of known istiophorid species in the western Atlantic, based upon published data and the writer's material . . .; this key should suffice for specimens from about 50 to 500 mm in length:

1a. Anus placed far forward, approximately midway between bases of anal and pelvic fins; pelvic fins short, not reaching nearly to base of anal fin; dorsal fin unspotted or mottled; dorsal spine count high, 45-53, modally 49 (see Robins and de Sylva, 1963, Table 5) . . . . . Longbill spearfish, *Tetrapturus pfluegeri*

1b. Anus placed close to anal fin base; pelvic fins long, reaching nearly to base of anal fin; dorsal fin variously spotted or mottled; dorsal spine count relatively low, 38-49 2

2a. Lateral line complex, partly forming a reticulated pattern (see Gehringer, 1957, Fig. 25; LaMonte, 1958, Pl. 75, Fig. 2; de Sylva, 1958, Pl. 81, Figs. 1-3; Caldwell, 1962, Fig. 1); bill short, only slightly longer than the mandible . . . . . Blue marlin, *Makaira nigricans*

2b. Lateral line simple, forming a single unit (LaMonte, 1958, Pl. 75, Fig. 3); bill long, greatly exceeding the length of the lower jaw 3

3a. Dorsal fin variously mottled, but without distinct ocelli at its base; anal fin pointed, pale, unmarked; dorsal spine count 40-49, modally 43 or 45; anal spine count 12-17, modally 13; dorsal soft-ray count 6-8, modally 7; anal soft-ray count 6-8, modally 7 (Voss, 1953, Fig. 4 and Gehringer, 1957, Fig. 15; see also Robins and de Sylva, 1963, Table 5, for frequency distribution) . . . . . Atlantic sailfish, *Istiophorus albicans*

3b. Dorsal fin variously mottled, but with four distinct ocelli near the base of dorsal fin (Fig. 1); anal fin broadly rounded, its middle rays dark; dorsal spine count 38-43, modally 42; anal spine count 13-19, modally 14 or 15; dorsal soft-ray count 5-7, modally 6; anal soft-ray count 5 or 6, modally 6 . . . . . .White marlin, *Tetrapturus albidus*

The present authors have identified the specimens of *T. albidus* they have examined by the combination of the above characters, but principally by the strongly rounded lobes of the first dorsal and first anal fins.

Subjective synonymy (from de Sylva, in press):

Tetrapturus belone: Sassi, 1846, Nuovi Ann. Sci. Rend. Sess. Soc. Accad. Sci. Hist. Bologna, ser. 2, VI: 391 (from Genoa; non *T. belone* Rafinesque, 1810). Placed in synonymy of *T. lessonae* Canestrini in Canestrini, 1861.

Tetrapturus lessonae Canestrini, 1861, Arch. Zool. Anat. Fisiol., Genoa, I (k): 259-261, pl. XVII (type locality: Ligurian Sea. Type specimen: a mount in the Museo di Storia Naturale di Genova). Placed in synonymy of *Makaira albida* (Poey) (= *T. albidus* Poey) in LaMonte (1955); reasons discussed.

Tetrapturus imperator: Jordan and Evermann, 1896, Bull. U.S. Natl. Mus., (47), I: 892 (*Tetrapturus albidus* Poey, 1860, considered a junior synonym of *T. imperator* Bloch and Schneider, 1801, which, however, is based upon *Xiphias gladius* Linnaeus, 1758). Placed in synonymy of *T. albidus* Poey in de Sylva (in press); reasons noted above.

Makaira lessonae Jordan and Evermann, 1926, Occas. Pap. Calif. Acad. Sci., XII: 56-57 (new combination based on *Tetrapturus lessonae* Canestrini, 1861). Placed in synonymy of *T. albidus* Poey in de Sylva (in press); reasons noted above.

Makaira albida Jordan and Evermann, 1926, Occas. Pap. Calif. Acad. Sci., XII: 66-67 (new combination based on *Tetrapturus albidus* (Poey, 1860)). Placed in synonymy of *T. albidus* Poey in de Sylva (in press); reasons noted above.

Tetrapturus belone: Legendre, 1928, Bull. Soc. zool. France, LIII: 391-392, fig. 1 (west of English Channel; *non T. belone* Rafinesque, 1810). Placed in synonymy of *Makaira albida* (Poey) (= *T. albidus* Poey) in LaMonte (1955); reasons discussed.

Tetrapturus belone: Desbrosses, 1938, Bull. Soc. zool. France, LXIII: 48-58 (200 miles west-northwest of Groix, Brittany; *non T. belone* Rafinesque, 1810). Placed in synonymy of *Makaira albida* (Poey) (= *T. albidus* Poey) in LaMonte (1955); reasons discussed.

Tetrapturus georgii: Tortonese, 1940, Boll. Mus. Zool. Anat. comp. Torino, XLVIII, ser. 3, no. 115, 3, 5, 6 (based on a mounted specimen in the Turin Museum, cat. no. 784; *non T. georgii* Lowe, 1840). Placed in synonymy of *Makaira albida* (Poey) (= *T. albidus* Poey) in LaMonte (1955); reasons discussed.

Lamontella albida Smith, 1956, Ichthyol. Bull. Rhodes, Univ., (2): 32 (new generic name for *Tetrapturus albidus* Poey, 1860). *Lamontella* placed in synonymy of *Tetrapturus* in Robins and de Sylva (1960); reasons discussed.

Tetrapturus belone: Lozano Cabo, 1958, Trab. Inst. esp. Oceanogr., XXV: 57, fig. 93 (Ceuta, Spain; *non T. belone* Rafinesque, 1810). Placed in synonymy of *T. albidus* Poey, 1860, in Robins and de Sylva (1960). Reasons not discussed.

Many additional name changes are listed by Nakamura et al. (1968).

Artificial key: Adult fishes of the genus *Tetrapturus*, modified from Nakamura et al. (1968):

a^1 Anterior fin rays of first dorsal fin fairly high posterior rays about same height; vent situated decidedly anterior to origin of the first anal fin; second anal fin anterior to second dorsal fin.

b^1 Pectoral fin narrow and short.

c^1 Snout very short . . . . . Shortbill spearfish *T. angustirostris* Tanaka.

c^2 Snout fairly long . . . . . Mediterranean spearfish *T. Belone* Rafinesque.

b^2 Pectoral fin wide and long . . . . . Longbill spearfish *T. pfluegeri* Robins and de Sylva.

a^2 Height of anterior portion of first dorsal fin about same as the body but as it goes gradual decreasing in height towwards posterior end; vent directly anterior to the origin of the first anal fin; second dorsal fin and second anal fin in parallel positions.

d^1 Pectoral fin wide and rounded. The tip of the first dorsal fin and first anal fin rounded. . White marlin *T. albidus* Poey.

d^2 Pectoral fin narrow, and its tip pointed; the tips of the first dorsal fin and first anal fin pointed . . . . . Striped marlin *T. audax* (Philippi).

1.22 Taxonomic status

The white marlin is a morphological species well described and taxonomically understood. Nakamura et al. (1968) in their review recognize only one species of white marlin which is universally accepted in the genus *Tetrapturus*.

1.23 Subspecies

We have found no descriptions of subspecies of *T. albidus*, or any evidence on which subspecies could be based.

1.24 Standard common names and vernacular names (Rosa, 1950; Miyake and Hayasi, 1972; de Sylva, in press)

Brazil - Bicuda, Agulhão branca, Espadarte meca
british West Indies - White marlin

Canada and France - Makaire blanc
Cuba - Aguja blanca, Cabezona, Blanca, Aguja de paladar
Japan - Nishimakajiki, Makajiki
Korea - Baeg-sae-chi
Morocco - Espadon
Portugal - Espadim branco do Atlantico, Espadim branco, Agulha, Espadim pequeño
South Africa - Wit marlyn (Afrikaans)
Spain - Pez aguja, Alfiler, Cometa, Altón
United States - White marlin, Skilligalee (New England)
USSR - Belyi marlin
Venezuela - Aguja blanca

1.3 Morphology

Our description of the morphology of *Tetrapturus albidus* is based on Poey (1861), LaMonte (1955, 1958a, 1958b), Robins and de Sylva (1960, 1963), Nakamura et al. (1968), Robins (1974), unpublished data collected by Mather and his colleagues, and other sources as cited. Proportions are expressed in percent of body length, with most measurements taken as defined by Rivas (1956). Additional measurements were taken as specified. The following abbreviations from Robins and de Sylva (1960) are used:

D^1 = first dorsal fin
D^2 = second dorsal fin
C = caudal fin
A^1 = first anal fin
A^2 = second anal fin
P^1 = pectoral fin
P^2 = pelvic fin
orig. = origin (in reference to fins)
c.p. = caudal pedencle

The word "ray," if not qualified, is used to designate fin elements without any implication as to whether they are spines or segmented rays.

1.31 External morphology

The body of the white marlin is of a modified fusiform shape, slender and notably compressed laterally (depth: greatest 14-19, near posterior margin of opercle; at orig. A, 12-16; c.p. 3.5-4.2; width: greatest 5.2-9.4, near orig. A; at c.p.[in front of keels] 2.7-3.8). The bill is like a spear, or, as the English name of the fish implies, a marlin spike. Its length is 25-35 from the edge of the eye, or 14-18 from the tip of the mandible. At the latter point, it is 0.81-1.3 deep and 1.2-2.0 wide, and at one third of the distance from the tip of the bill to the tip of the mandible Poey found the depth to be 0.5-0.6 of the width.

The head (24-27) tapers very rapidly from a pronounced dorsal hump over the opercles to a beak-like mouth formed by the bill and the sharply pointed lower jaw. Its dorsal and ventral profiles are concave anteriorly and convex posteriorly. The mouth opening is large (maxillary 15-17), extending beyond the posterior margin of the fleshy orbit by about one-third of its diameter, which is 2.8-3.2. The eye is about midway between the tip of the mandible and the operculum and the preoperculum about midway from the eye to the operculum. The nostrils, each consisting of two openings, are about two thirds of the diameter of the eye ahead of its anterior margin.

The body depth tapers gradually from the opercular area to the first anal fin, then more rapidly to the origin of the caudal.

A pair of horizontal cartilaginous keels (2.7-4.7), one above the other, is located on each side of the caudal peduncle, orginating in nearly the same longitudinal position as the caudal fin. The caudal fin is stiff, powerful, and deeply forked. Its spread is 33-43, and an angle of 80° between the posterior margin (disregarding the tips) and the centerline was reported for the type specimen. Poey lists 12 caudal rays for the type specimen, and Goode (1881) gives a count of 6 + 4 + 4 + 5 for a specimen collected off New Bedford, Mass.

The first dorsal, first anal, and pelvic fins disappear completely into dorsal and ventral groves when not in use. The pectorals fit flush with the sides of the fish in slight depressions in the body, but the second dorsal and second anal fins are not retractable. Poey (1861) described the characteristics and arrangement of the rays of these fins in detail. Their counts are: D_1 - 38-46 (usually 40-43); D_2 - 5-7 (usually 5-6); A_1 - 12-18 (usually 14-16); A_2 - 5-7 (usually 6); P_1 - 17-22 (usually 19-21); and P_2 - 5. Frequency distributions of D_1, D_2, A_1, A_2, and P_1 counts for white marlin from the eastern

Table 1.—Fin-ray counts of western[1] and eastern Atlantic white marlin, *Tetrapturus albidus*.

	Dorsal spines								D_2 rays			Anal spines						A_2 rays			P_1 rays[2]					
	38	39	40	41	42	43	44	45	5	6	7	13	14	15	16	17	18	5	6	7	17	18	19	20	21	22
Western Atlantic	1	3	8	10	11	9	-	-	20	21	1	4	18	18	5	-	-	2	41	-	1	2	6	23	9	-
Eastern Atlantic	-	1	7	16	19	8	5	1	26	30	-	2	9	28	12	3	2	5	50	1	-	2	10	30	13	1

[1] Data from Robins and de Sylva (1960: Table 1).
[2] Only the left pectoral fin was counted.
Source: Robins, 1974, Table 1.

and western North Atlantic are presented by Robins (1974) (Table 1). The first dorsal fin originates over the posterior margin of the preopercle (first predorsal length 22-25) and extends nearly to the origin of the second dorsal (base of first dorsal 55-58). From a rounded anterior lobe (anterior height 14-23), somewhat higher than the depth of the body below it, the height of this fin diminishes, first rapidly and then more gradually (25th spine 4.0-6.2), until the last few rays are hidden in the dorsal groove. The first anal fin is somewhat similar, but lower and much shorter (anterior height 12-16, base 14-17). It originates 57-62 (first preanal length) behind the tip of the lower jaw, and 3.7-5.2 behind the vent. After the anterior lobe, which is usually broadly rounded, the height decreases rapidly, then more gradually, until the last rays are hidden in the ventral groove. The second dorsal and second anal fins are very similar, and are located nearly opposite each other (second predorsal length 77-83; second preanal length 75-81) close behind the first dorsal and first anal fins. They are small (anterior height D_2 - 3.1-4.7; A_2 - 2.8-3.9; length of base: D_2 - 3.6-4.6; A_2 - 4.0-4.9; length of last ray: D_2 - 4.2-7.2; A_2 - 4.8-6.7), with short slightly convex leading edges and long deeply concave trailing edges, terminating in long points. The ultimate rays are broad and flattened proximally and adhere closely to the body of the fish.

The pectoral fin is moderately long (19-27), and its tip is usually rounded. Its origin is just behind the opercle (prepectoral length 25-27) and low on the side of the fish (distance from orig. D_1 to orig. P_1 12-14). About eight of the lowest rays are very short, forming a subbrachial dilatation.

The pelvic fins, which also originate near the opercle (prepelvic length 26-29), are somewhat shorter (length 14-22) and are so narrow that their area is negligible, and they appear to consist of a single spine. Poey (1861, pl. 16, figs. 4 and 5; the explanation of the plate [p. 241] mistakenly refers to these figures as of the pectoral) describes the structure of this fin in detail.

The color of the white marlin has been described by Poey (1861), Goode (1881), LaMonte (1955), and Nakamura et al. (1968). The back and the top of the head are described as dusky blue, and the back also as brilliant greenish blue, darker above (LaMonte, 1955). The underparts are silvery white. The transition from the dark dorsal to the white ventral areas is gradual, passing through lines of rich purplish brown and smokey grey (Goode, 1881). The sides are crossed by vertical light blue or light lavender bars (LaMonte, 1955). The cheeks and opercles are dusky, with a pearly sheen. The membrane of the first dorsal fin is deep blue or bluish purple, with circular dusky spots near its base. The rays are dark blue or black. The first anal fin is dark blue or bluish purple distally, and pearly white proximally. The second dorsal is a deep blue, and the second anal is somewhat lighter blue. Outer surfaces of the pectorals are dusky with a pearly sheen, and the inner surfaces bluish purple. The pelvics are blue black. The caudal is dusky bluish or brownish, sometimes with pearly reflections in the lower lobe, and the caudal keels are bluish black.

The colors change in response to the state of excitement of the fish. Jaen (1964) states that when a billfish following a bait is pale green, it probably will not strike, but if it is dark-colored and its fins are shiny bright blue, it will strike immediately. The pectoral fins of the white marlin "light up" especially brilliantly in these circumstances.

The lateral line of the white marlin is simple and more conspicuous than those of other Atlantic istiophorids. The lateral line originates at the top of the opercular aperture, whence it runs longitudinally for a short distance, then curves away from the back and reaches the median line of the fish near the tip of the pectoral. The lateral line was described in some detail by Poey (1861) and Talbot and Penrith (1963), but LaMonte (1958a) has made the most detailed study of the lateral line, scales, and skin of the white marlin now available. The lateral line is 4 mm wide (6-8 mm, according to Talbot and Penrith, 1963). Specialized subcutaneous overlapping lateral line scales have a complicated system of holes and ducts leading through holes in the surface of the skin to the exterior. These scales roof a relatively wide continuous tube (Talbot and Penrith, 1963). Nonspecialized subcutaneous scales are thorn shaped, regular, and only occasionally and slightly overlapping. They show very clearly externally, but are completely contained in fibrous integument, and also completely covered by the outer skin of the fish. The surface scales are very small and delicate, with round, radially marked bases and glassy perpendicular spines. There are small round openings through the skin under many of these scales. A histological description of marlin skin by Rasquin is included in LaMonte (1958a).

The gills include four double arches and an accessory, reticulated as in swordfish (Poey, 1861). LaMonte (1958b) states, for billfish in general "The wide laminated gills are paired; each pair is connected from the base to within a short distance of the free margins, as if woven together. Gill-rakers are absent or vestigial. This gill structure is typical of the group." We have not found gill rakers on any of the white marlin which we have examined.

Poey (1861), LaMonte (1958b), and Nakamura et al. (1968) discuss the dentition of white marlin briefly. The dentition is weak, consisting of small patches of denticles or villiform teeth on the jaws, palatines, palatine membrane, and pharyngeals. Poey also mentions anteriorly directed denticles on the sides of the bill.

1.31a Internal morphology[3]

The nostrils are separated by a cup-shaped space but are enclosed in a common cavity (Poey, 1861). The olfactory rosette is radially shaped and has 44-50 nasal lamina, the distribution of blood vessels on which cannot be seen with the naked eye (Nakamura et al., 1968). The structure of the skull and bill are well described by Poey (1861) and Nakamura et al. (1968). The following description of the skull and of vertebral characteristics are from the latter authors.

> The cranium is hard, elongated, and on the whole, long and thin. The post-occular portion of the head is short. The anterior, ventral side of the vomer and the parasphenoid is rather thin. The temporal crest and the pterotic crest run almost parallel to each other. There is a small and fairly well developed projection on the upper back side of the frontal bone.
>
> The haemal spines and the neural spines of the vertebrae form an elongated parallelogram. The lateral apophysis is poorly developed. There are 24 vertebrae (12 + 12 = 24).

The vertebral characteristics of white marlin and other istiophorids were discussed and compared in detail by Ueyanagi and Watanabe (1965), and Monod (1968, Fig. 784) described the osteological structure of the caudal region. Morrow (1957) studied and compared the morphology of the pectoral girdle in the genus *Makaira*, including *T. albidus*.

The internal organs of white marlin were described briefly by Poey (1860) and Nakamura et al. (1968), and Krumholz (1958) provided information on relative weights of some of the viscera. The following description is abstracted from the more comprehensive work of LaMonte (1958b), from which we show the ventro-lateral aspect of the viscera (Fig. 3). The kidneys lie at the top of the body cavity against the vertebrae. The peritoneum separates them from the long, physoclystic air bladder, which consists of a double row of bubblelike chambers closed in a common outer membrane. The stomach is at the anterior end of the body cavity, and below it, anteriorly, are the caecal mass, capped by the liver, and the heart. The spleen is below the stomach on the left side, behind the caecal mass. Adjacent to it is the intestine, which makes one coil upon itself and runs along the body wall to the vent which lies in a ventral groove with the urinogenital opening. The gonads lie on either side of the stomach. Krumholz (1958) presented the relative weights of different organs of 42 white marlin caught off the Bahamas in percentage of the weight of the fish, and discussed their variations with the size and sex of the fish.

No analyses of geographic variations in morphological characters were found in the literature, and consequently no subpopulations have been defined on this basis.

Morphological changes with growth have not been well defined, since nearly all of the available morphological data is for adults, and no thorough compilation and analysis of this have been published. Robins and de Sylva (1960), pointed out that the development of the bill in *Tetrapturus albidus* and other "Tetrapturinae" was negatively allometric. The bill length (30) of the 125 mm (body length) postlarva described by de Sylva (1963), however, falls in the range for adult material (25-35). The first dorsal fin of this specimen is high medially (25th ray 30) and saillike. The pectoral fin is much shorter than in adults (10.7 vs. 19-27) and the pelvic much longer (29.6 vs. 14-22). The body is more slender and compressed (greatest depth 11 vs. 12-18, greatest width 5.8 vs. 5.2-9.4, usually 7.5-8.5), with the greatest width near the orgin of the pectorals rather than near the origin of the first anal fin as in adults.

Data (unpublished) for two specimens of intermediate size (904- and 964-mm body length) examined by C. R. Robins and Mather are available. In general, these individuals had attained adult proportions except that the central part of the first dorsal fin remained higher (14.7 vs. 3.1-4.7), the pectorals

[3]This section heading has been introduced by the authors since the outline provides no place for this material.

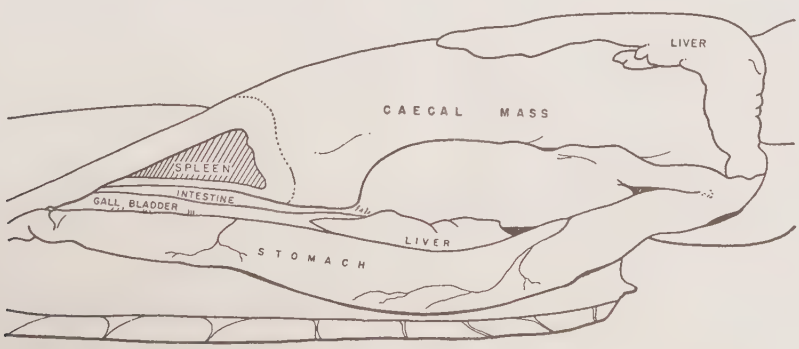

Figure 3.—Diagram of *Makaira albida*, showing ventral-lateral aspect, with caecal mass reflected to left. Approximately natural size. Dissection by Francesca R. LaMonte. Drawing by Janet Roemhild. (From LaMonte, 1958b, Fig. 13 and caption.)

shorter (17.5-19.2 vs. 19-27), and the pelvics longer (26.0-26.7 vs. 14-22). The larger of these was described by de Sylva (1963) as having the adult characteristics nearly fully developed.

1.32 Cytomorphology

The genetic make up of the white marlin has not been dealt with in any detail.

1.33 Protein specificity

Edmunds (1972) analyzed samples from over 100 white marlin captured in the middle Atlantic Bight, off the Bahamas, in the northern Gulf of Mexico, and off Venezuela electrophoretically for the forms of the proteins transferrin, esterase, 6-phosphogluconate dehydrogenase (PGD), malate dehydrogenase (MDH), hemoglobin, lactate dehydrogenase (LDH), and glucose 6-phosphate dehydrogenase (G6PD) present. He concluded that these analyses provided no basis for separating the white marlin from these areas into different subpopulations.

2 DISTRIBUTION

2.1 Total Area

The white marlin is distributed over nearly all of the Atlantic Ocean from lat. 35°S to 45°N, including the Gulf of Mexico and the Caribbean Sea (Figs. 4, 5). Most of this range is documented by catches of the Japanese longline fishery (Ueyanagi et al., 1970; Mather, Jones, and Beardsley, 1972). Data from other fisheries (Furnestin et al., 1958; Postel, 1959; Rodriguez-Roda and Howard, 1962; Robins, 1974), however, establish the presence of the species in the eastern North Atlantic near the Strait of Gibraltar. The white marlin has occasionally been recorded outside this area, perhaps on the basis of strays. Legendre (1928) and Desbrosses (1938) reported individual captures west of Brittany, France, Tortonese (1940, 1961, 1962, 1970), Lozano Cabo (1958), and Rodríguez-Roda and Howard (1962) recorded a few catches in the western Mediterranean. Also, Japanese longliners have taken a few white marlin near lat. 45°S and long. 50°W, and near lat. 40°S and long. 15°E (Ueyanagi et al., 1970). The distribution of the Japanese longline effort does not provide complete coverage of the Atlantic Ocean in all seasons. Therefore the seasonal distribution of the species and the limits of its normal range, particularly in the South Atlantic, may not be completely defined.

Pollutants such as chlorinated hydrocarbons (Harvey et al., 1972), petroleum (Horn, Teal, and Backus, 1970; Morris, 1971), and plastics (Carpenter et al., 1972) have found in the surface waters of areas inhabited by white marlin, but what effect, if any, these may have on this species is unknown.

The known distribution encompasses most of areas (Rosa, 1965) ASW (Atlantic, SW) and ASE (Atlantic, SE), as well as the part of ANW (Atlantic, NW) south ot lat. 45°N, and the Atlantic portions of PSW (Southern Ocean, W) near South America and Africa. Natural regions (Rose, 1965) included are the Newfoundland waters (5.2.1); the Florida, Gulf Stream, and Atlantic Drift Current waters (5.3.1-.2,-.3 [rarely]); the Sargasso Sea and Azores waters (5.4.1-.2); the western part of the Mediterranean Sea (5.5.1 [rarely]); the Gulf of Mexico, Carribean Sea, Bahama, Atlantic North Equatorial Current, and Cape Verde waters (5.6.1,-.2,-.3,-.4,-.5); the Guinea region (5.7); the Atlantic South Equatorial Current region, E. Brazilian, S.E. Brazilian, Benguela Current, and S.W. African waters (5.8.1-.2,-.3,-.4,-.5); the Atlantic southern gyrals (5.9.1); and the Agulhas waters (1.5.4 [rarely]).

This area is so large that it is difficult to classify. The distribution varies seasonally, however, reaching the higher latitudes in the respective hemispheres during the local warm seasons only. For the most part, white marlin are found in deep (over 100-m) blue water with surface temperatures over 22°C and salinities of 35-37‰. Some seasonal feeding concentrations and migrations, however, occur in waters with characteristics differing from one or more of these. Average air temperatures of regions where white marlin occur are usually moderate to warm, 15°-28°C. Currents of from 0.5 to 2 knots occur over much of their habitat. The productivity of most of this distributional area is considered to be low.

2.2 Differential Distribution

2.21 Spawn, larvae and juveniles

The early stages of the life history of white marlin are little known. As a result of collections of larvae 3.0-3.5 mm long made from RV *John Elliot Pillsbury*, 24 July-13 August 1964, de Sylva postulated three spawning grounds for white marlin in the western North Atlantic (Stephens, 1965). These were northeast of the Little Bahama Bank, off Abaco Islands, northwest of Grand Bahama Island (both in region 5.6.2), and southwest of Bermuda (region 5.4.1). Ueyanagi et al. (1970) state that white marlin migrate to subtropical waters to spawn, with peak spawning in early summer. They record collections of larvae at only a few of a very large number of collecting stations (Fig. 6) in November-April. Four collections were made in the central South Atlantic (near lat. 20°N, long. 20°W). Two were in the western South Atlantic; one near lat. 22°S and long. 32°W, and one near lat. 8°S and long. 35°W, just off the easternmost part of Brazil. Two were in the central North Atlantic, near lat. 20°N and long. 35°W. Another was in the western North Atlantic, near lat. 8°N, long. 50°W.

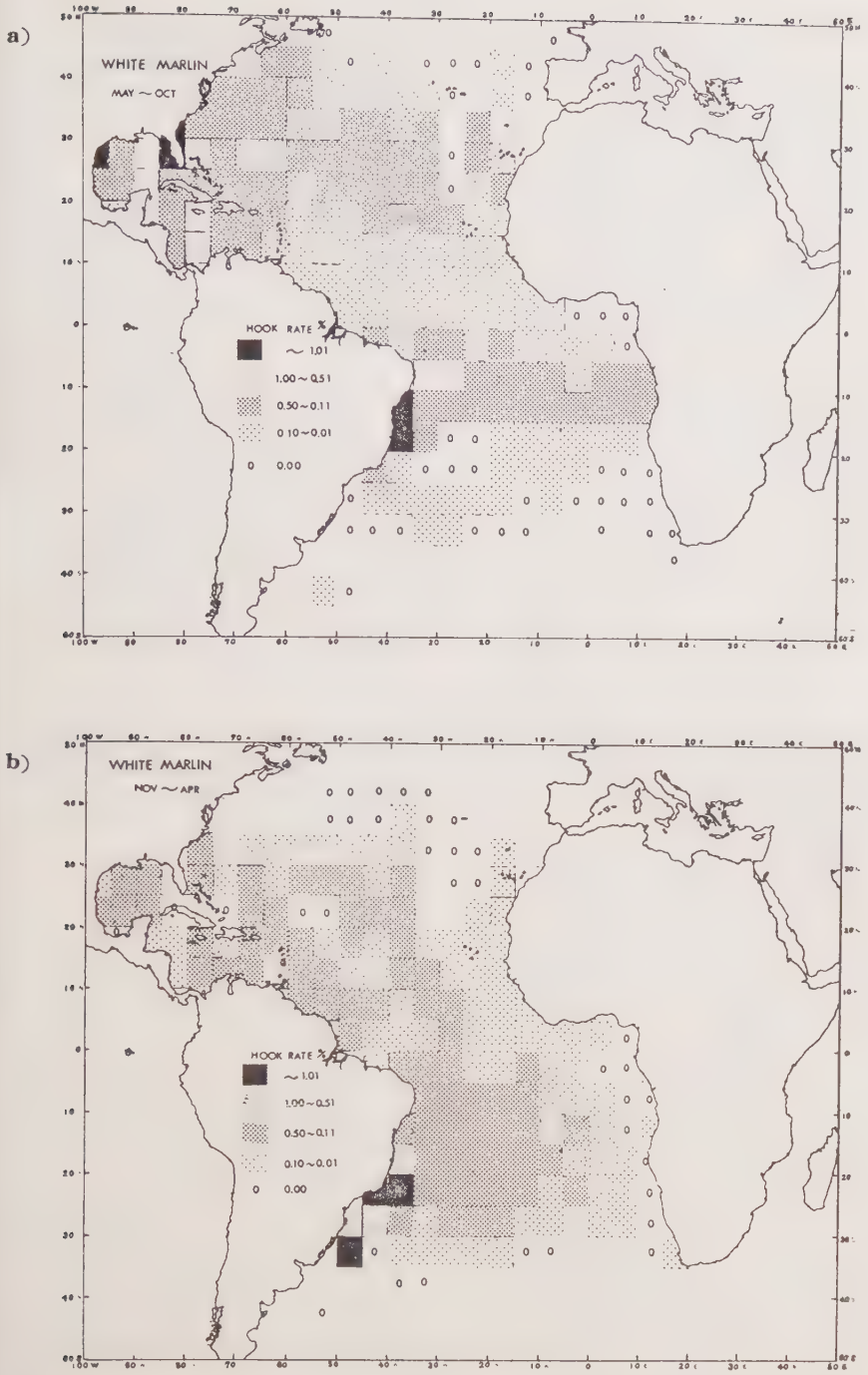

Figure 4.—Distribution of white marlin by season: a) May-October; b) November-April. (From Ueyanagi et al., 1970, Fig. 18 and caption.)

Ueyanagi (1959) suggested that some of the larvae identified by Gehringer (1957, Figs. 6, 10, 14) as sailfish might have been white marlin. These specimens were collected in the western North Atlantic, from Cuba to the Carolinas, in May-September.

Hayasi et al. (1970)[4] state that the high hook rate off southern Brazil in November-April is associated with the appearance of large-sized fish, which, with the appearance of postlarvae and juveniles, assures that this is an immigration of spawning adults. They note that "White marlin seem to spawn rarely in the equatorial waters", but that "matured adults appear in the northern Caribbean Sea and off Florida during

[4]The material in Hayasi et al. (1970) is a summary of English of the material which was presented by Ueyanagi et al. (1970) in Japanese, except for a synopsis, table and figure captions, names of fishes, and English language references, which were presented in English (S. Hayasi, pers. commun.).

Figure 5.—Distribution and apparent relative abundance of white marlin in the Atlantic Ocean. Data are from records of the Japanese longline fishery, 1956-67. The catch per unit of effort (CUE) for each month in rectangle is the arithmetic mean of the CUE of each month that the area in the rectangle was fished in the 12-yr period. CUE is the number of fish caught per 100 hooks. (From Mather et al., 1972, Fig. 6 and caption.)

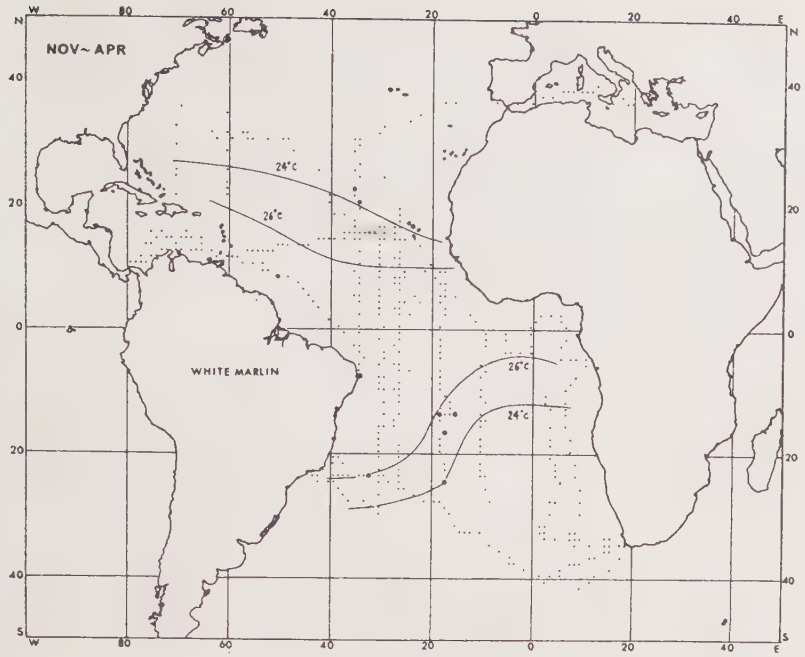

Figure 6.—Distribution of larvae of white marlin, November-April. Large dots - larvae present; small dots - larvae absent. (From Ueyanagi, 1970, Fig. 21 and caption.)

April through June. Collection of juveniles in January in the adjacent waters, Lat. 10°N and 20°N, Long. 35°W and 60°W, suggests long lasting spawning season of the species."

2.22 Adults

Adult white marlin are very widely distributed over the warm parts of the Atlantic Ocean and the adjacent seas, but the degree of concentration, or apparent abundance, varies greatly, both geographically and seasonally.

The catch and effort statistics of the Japanese longline fishery comprise the most comprehensive mass of data on the distribution and apparent relative abundance of adult white marlin available. The effort and the catches of each species tabulated by months and 5° (latitude and longitude) quadrangles, and distributional charts of catch and effort, for the first years of the fishery, 1956-62, were published by Shiohama, Myojin, and Sakamoto (1965). Similar data and charts for each of the years 1962-70 were published by the Research Division of the Fisheries Agency of Japan (1965, 1966, 1967a, 1967b, 1968, 1969, 1970, 1971, 1972) in its annual reports of effort and catch statistics of the Japanese tuna longline fishery. Several authors have organized this enormous mass of data, including that for white marlin, into more compact form. Wise and Le Guen (1969) presented catch rates by years, months, and areas for 1956-63. Wise (1968) and Wise and Fox (1969) made similar analyses of the data for 1964 and 1965. Wise and Davis (1973) show the average catch rates for the years 1956-69 for each quarter of the year by contours (Fig. 7). We have added indications of seasonal coastal occurrences to these charts. Ueyanagi et al. (1970) have also presented a thorough analysis, showing catch rates by half-year periods (Fig. 4) and by months. Mather et al. (1972) presented the average catches for white marlin for the years 1956-67 by months (Fig. 5). Our discussion of the oceanic distribution of adult white marlin is based mainly on these sources.

In the South Atlantic, white marlin concentrate in the eastern side off Angola, in June-July, and on the western side off Brazil and sometimes in the center, for most of the rest of the year (Figs. 5, 7). The concentration off Brazil centers off Recife in September and October, but extends southward to the vicinity of Rio de Janeiro. In November the concentration moves to the south and also well to the east. In December-February the catch rates are highest off Rio de Janeiro, but isolated areas of concentration occur to the east-ward, in the central and eastern parts of the ocean. March-May is a period of generally low catch rates, except for isolated areas off easternmost and southernmost Brazil. Concurrently with the June-July concentration of white marlin off Angola there are small areas of high catch rate off easternmost Brazil, and in July in mid-ocean between these two areas. Perhaps because of the limited development of sport fisheries in the South Atlantic, no important coastal concentrations of white marlin have been found in that ocean.

A few isolated records, however, supplement the data provided by the Japanese longline fishery on the distribution of white marlin in the South Atlantic. LaMonte (1955) reported that the species occurs off Cabo Frio, Brazil, December-February. During a visit to the Yacht Club at Rio de Janeiro in January 1969, the senior author was informed that sport fishermen

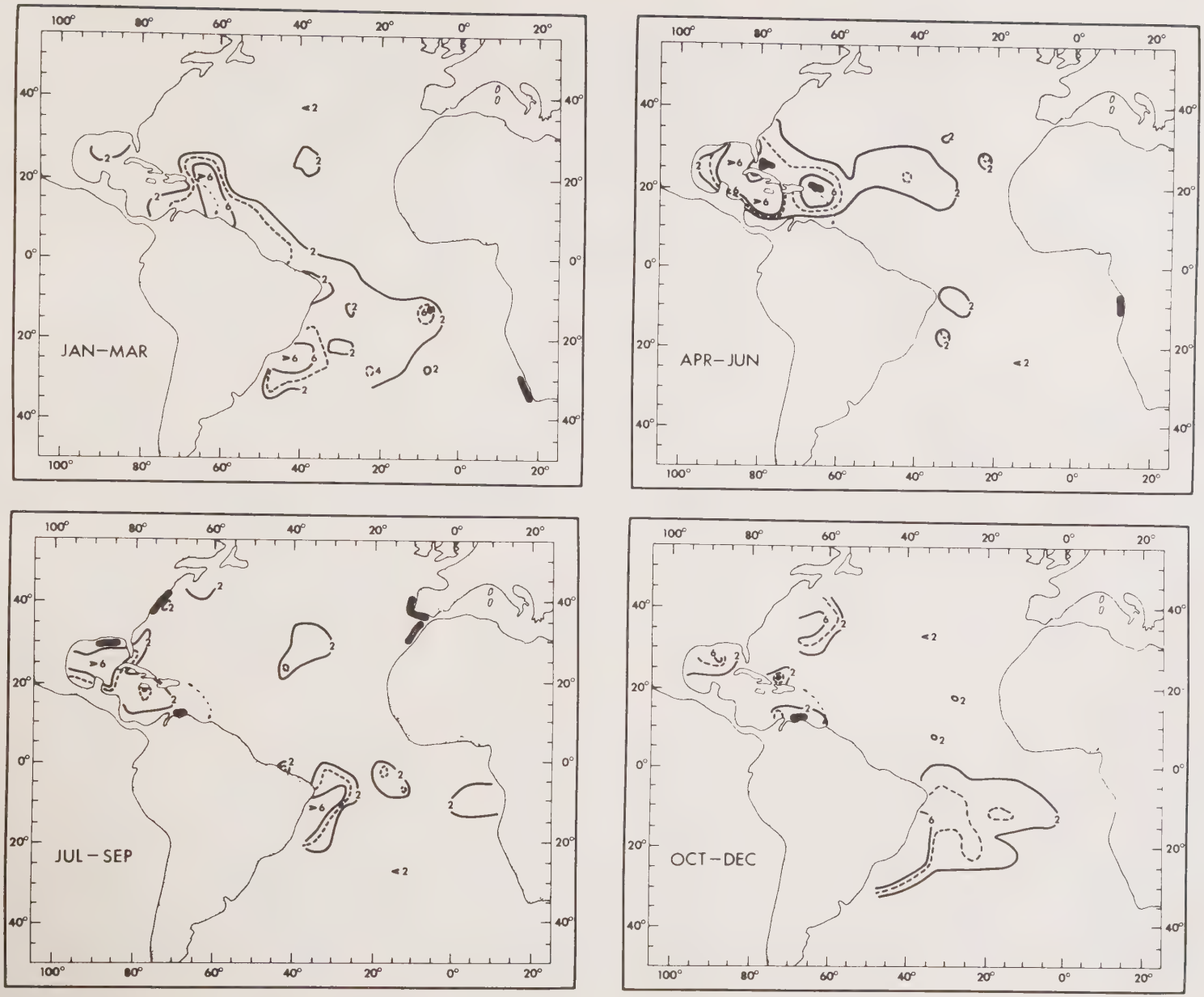

Figure 7.—Distribution of catches of white marlin (per 1,000 hooks) in the four quarters of the year, 1956-68. (From Wise and Davis, 1973, Fig. 9 and caption.) Coastal concentrations indicated with — were added.)

occasionally caught white marlin off that city. Talbot and Penrith (1962, 1963) recorded single captures of white marlin off Cape Town, South Africa, in March 1961 and February 1962; 110 miles north-northwest of Walvis Bay, South West Africa in April 1961; and off the island of St. Helena (no date reported). These authors also noted that in the summer of 1961, three striped marlin, *T. audax*, were caught in the same area as the white marlin. Records of the Game Fish Union of Africa (Anon., 1972b) show two additional white marlin, 63 pounds (28.6 kg) and 111 pounds (50.5 kg), caught off St. Helena on 17 February 1958 and 16 February 1961, respectively.

The information on the distribution of white marlin in the North Atlantic obtained from the oceanic fisheries is supplemented by studies of important seasonal coastal concentrations and records of occasional occurrences in various localities. Peak inshore sport fishing and offshore longline fishing do not necessarily coincide seasonally in each area, probably because of differences in distribution relative to depth of water, and changes in swimming depth and feeding habits.

In summer, the peak longline catches are in the Gulf of Mexico and the northwestern Caribbean. Low catch rates (Figs. 5, 7) over extensive areas indicate that white marlin are widely but thinly distributed over much of the deep waters of the open North Atlantic during this season.

The most important inshore concentrations in summer and early fall are on and near the edges of the continental shelf in the northern Gulf of Mexico, from Cape Hatteras, N.C., to Cape Cod, Mass., and off La Guaira, Venezuela. A less known concentration in late summer and early fall occurs outside the Strait of Gibraltar.

Gibbs (1957) studied seasonal variations of longline catches in relation to water temperature in the Gulf of Mexico. He noted a summer concentration off the Mississippi Delta, which dispersed as the water cooled in fall. This concentration and another at the De Soto Canyon in the northeastern Gulf contribute importantly to sport fisheries based at New Orleans, La.; Mobile, Ala.; and Pensacola, Panama City, and Destin, Fla. (Mather et al., 1972; Nakamura and Rivas, 1972). Some successful sport fishing for white marlin has also occurred at the edge of the continental shelf off Port Aransas, Tex. (M. H. Weil, pers. commun.). White marlin are available to the sport fisheries in the Gulf from early June into October, with peak abundance off the delta in July and at the De Soto Canyon in August.

The concentration of white marlin which supports the largest sport fishery for this species in the world occurs in summer between Cape Hatteras and Cape Cod (Farrington, 1937, 1949a, 1949b; Earle, 1940; June and Reintjes, 1957; Migdalski, 1958; de Sylva and Davis, 1963; Brooks, 1968). The greatest concentration of fishing is between Oregon Inlet, N.C., and Atlantic City, N.J. In the earlier years, most of this fishing was within 30 or 40 miles of shore, on shoals such as the famous "Jack Spot" off Ocean City, Md., and other productive areas. In recent years, however, most of the successful fishing has been nearly 80 miles offshore, concentrating around the canyons at the edge of the continental shelf, from Norfolk Canyon off the Chesapeake Capes to Block Canyon off eastern Long Island.

The northeastern limit of the usual summer coastal occurrence of white marlin is off Nantucket Island, south of eastern Cape Cod, Mass. The species occurs further east and north on Georges Bank and the Nova Scotia Banks, especially along their oceanic edges (Farrington, 1949b; J. S. Beckett, pers. commun.) but rarely enters the Gulf of Maine. We know of only two records from coastal waters in the Gulf. Both were from traps at Provincetown, Mass. (John A. Worthington, pers. commun.). The first of these specimens, taken in August 1960, was deposited in the Museum of Comparative Zoology, Harvard University, Cambridge, Mass., as the first positive record of this species from the Gulf of Maine. Farrington (1949b), however, reports occurrences off the coast of Nova Scotia.

A concentration of white marlin in late August, September, and October off La Guaira, Venezuela, furnishes some of the world's best sport fishing for this species (Migdalski, 1958; Jaen, 1964; Brooks, 1968).

In late September and October after the conclusion of the sport fishing season between Cape Hatteras and Cape Cod, longline catch rates are high from the edge of the adjacent continental shelf eastward to long. 55°W. They are also good in the northern Gulf of Mexico in this period. Longline catch rates are low everywhere in the North Atlantic in November, but improve in the southeastern Caribbean in December. January has also been a poor month throughout the North Atlantic, but in February and March there have been good catches off the coast of South America from Venezuela to the equator. In March, this area of good fishing extends northward around the Lesser Antilles, the Virgin Islands, and Puerto Rico up to lat. 25°N. In April, the concentration of catches has been between lat. 15° and 25°N and long. 55° and 75°W, but there was little fishing effort further west in these latitudes. In May, the area of successful fishing extends further to the south (off western Venezuela and Colombia and northeast of Cuba and the Bahamas). June finds good longline fishing in the western Caribbean, the northern Gulf of Mexico, and east of the Bahamas and northern Florida.

Spring is the peak season for inshore sport fishing for white marlin in the Straits of Florida and among the Bahamas. Areas which support important sport fisheries for this species are Havana; Bimini and Cat Cay on the northwestern edge of the Great Bahama Bank; the Berry Islands at the northern end of the Tongue of the Ocean; and Walkers Cay at the

northern tip of the Bahamas (Farrington, 1937, 1949a, 1949b; Hemingway, 1949; Migdalski, 1958; Brooks, 1968). This period is also the most productive for sport fishing for white marlin off southeastern Florida, Puerto Rico (Erdman, 1957), and the Virgin Islands.

White marlin apparently are less abundant in the eastern North Atlantic and the Mediterranean, but have been recorded occasionally in those waters. LaMonte (1955) reports catches off "Portugal, Azores Islands, Madeira, and the Italian Riviera." Legendre (1928) and Desbrosses (1938) reported single captures of *T. belone* and *T. Lessonae*, respectively, both taken in September from tuna fishing boats well off Brittany (west of the entrance to the English Channel and "200 miles from Groix," respectively). Both records have been placed in the synonymy of *T. albidus* (LaMonte, 1955). Rodríguez-Roda and Howard (1962) reported on 19 specimens of white marlin captured off the southern coasts of Portugal and Spain in 1961—16 in August, 1 in September, and 2 in October. Thirteen of these captures were in the Atlantic, 2 in the Strait of Gibraltar, and 4 at La Linea, Spain, just inside the Mediterranean Sea. Robins (1974) lists 37 specimens caught off southern Portugal in late July and August 1961, and 2, observed by Mather, which were caught off Cadiz, Spain, on 6 October 1969. Twenty-three of these fish were caught by hook and line (most, if not all, by longline), and 35 by tuna traps (almadrabas). Furnestin et al. (1958) describe two specimens taken off Morocco, one by longline off Mazagan, August 1950, and one by trawl net off Casablanca, July 1953, and state that the species is taken very frequently by longline off Tangier and in the vicinity of Casablanca. A photograph (Lozano Cabo, 1958, Fig. 93) of a fish caught in a tuna trap at Ceuta, Spain (African coast, just inside the Mediterranean) is captioned and referred to as *T. belone*, but we concur with Robins and de Sylva, 1960, in re-identifying this fish as *T. albidus*. This information indicates that white marlin are fairly abundant in the Atlantic approaches to the Mediterranean in August and September, and occasionally enter the western part of the Alboran Sea.

Records of *T. albidus* in the remainder of the Mediterranean, however, are very scarce. Tortonese (1940, 1961, 1962, 1970) re-identified two mounted specimens, which had been caught near Genoa, Italy, in the nineteenth century, as *T. albidus* and reported the capture of two others in a small tuna trap 23 km east of that city in September 1970. In his opinion, the species occurs only in the western part of the Mediterranean, and is very rare there. Cesareo (1967) recorded the harpooning of a white marlin in September 1967, near the Island of Gallinara in the Ligurian Sea. Sarà (1968) noted that *T. albidus* contributed to the catches of some Sicilian tuna traps, and Bini (1968) (not seen by us, but quoted by Tortonese, 1970), also stated that this species occurs in Sicilian waters.

Annual variations in distribution are most notable in areas where the distribution is seasonal, especially near the limits of the range of the species. These variations are usually attributable to one or more of the determinants of distribution changes (see 2.3).

2.3 Determinants of Distributional Changes

The distribution of white marlin is controlled primarily by the necessities of feeding and spawning, and secondarily by conditions of the environment.

The spawning areas of white marlin have not been completely defined, but it appears that some coastal concentrations (Bahamas [de Sylva and Davis, 1963; Stephens, 1965], Cuba, and the Greater Antilles [Erdman, 1956]) are related to spawning, while others (northern Gulf of Mexico [Gibbs, 1957], Cape Hatteras-Cape Cod [de Sylva and Davis, 1963], Venezuela [Jaen, 1964], and outside the Strait of Gibraltar [Robins, 1974]) are related to feeding. The latter are all in areas of relatively high productivity.

It also appears that the oceanic concentration off southern Brazil is a spawning assembly (Hayasi et al., 1970).

Water temperature appears to exert an important influence on the distribution of white marlin. Gibbs (1957) related the monthly changes in the distribution of white marlin catches in the Gulf of Mexico to the position of the 75°F (23.9°C) isotherm. Ovchinnikov (1970) stated that a temperature of 24°C is optimal for white marlin. Squire (1962) showed that at exploratory longline stations where white marlin were caught by MV *Delaware* and RV *Crawford* in the western North Atlantic, surface temperatures ranged from 70.0° to 83.0°F (21.1° to 28.3°C), with a weighted average of 76.6°F (24.8°C), and temperatures at the estimated fishing depth (estimated as 173 feet or 52.7 m) ranged from 50.0° to 80.5°F (10° to 27°C), with a weighted average of 68.8°F (20.5°C). De Sylva and Davis (1963) showed, from extensive observations taken of southern New Jersey and Maryland during the summer of 1959, that the white marlin grounds were generally characterized by surface water temperatures between 78° and 80°F (25.6° and 26.7°C). Most of the longline catches of white marlin have been on the warm side of the 20°C surface temperature isotherm (Fig. 4.)

Ovchinnikov (1970) reported that commercial concentrations of white marlin occur near shores in areas where less saline coastal waters mix with more saline oceanic waters. De Sylva and Davis (1963) noted that in the summer of 1959 the white marlin grounds off southern New Jersey and Maryland were of higher salinity than the surrounding inshore waters, and were identifiable by an abrupt increase from lower to higher salinity values. Those off Ocean City, Md., were further characterized by low oxygen values surrounded by high values. Important white marlin areas showed distinctly high plankton volumes.

The color of water appears to be an indicator of probable abundance of white marlin. Nakamura (1971) and Nakamura and Rivas (1972) found that angling success for white marlin in the northern Gulf of Mexico was greater in proportion to the blueness of the water, and poorer in proportion to its greenness. During the 1972 season, there was an unusual occurrence of green water at the normally productive white marlin fishing areas at the edge of the continental shelf off Maryland and southern New Jersey, and catches in this water were very poor (M. Maiorana, pers. commun.). In similar areas off Virginia and North Carolina, the water was the normal blue color, and the fishing for white marlin was excellent, indicating that the poor fishing further north was not due to a scarcity of fish.

In some areas, white marlin are concentrated near rips (usually occurring at interfaces between different masses of water), or weed lines.

Differential distribution of white marlin is also influenced by bottom topography. Steep drop-offs, submarine canyons, and shoals, when located in areas with suitable water conditions, are often the scene of important feeding concentrations of white marlin and exceptionally productive fishing. Shoals of this nature include the Placer de la Guaira, off the Venezuelan port of that name (Jaen, 1964), the "Cigar" off the Virginia Capes, the "Jack Spot" off Maryland (Farrington, 1937, 1949a, 1949b; de Sylva and Davis, 1963), and the Five Fathom Shoal of southern New Jersey (de Sylva and Davis, 1963). Drop-offs producing good white marlin fishing are found in many areas, including the Bahamas, Cuba, Puerto Rico, and the Virgin Islands. In recent years, excellent fishing for white marlin and other oceanic game fishes has developed at many of the canyons along the edges of the continental shelf. Among the more important are the De Soto Canyon in the northeastern Gulf of Mexico; Norfolk Canyon off the Virginia Capes; Washington, Baltimore, and Wilmington canyons off the Delmarva Peninsula; and Hudson Canyon off New York City.

2.4 Hybridization

No information was found in the literature.

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

The white marlin is heterosexual. No apparent external sexual diamorphism exists, except that the females attain larger sizes than the males (de Sylva and Davis, 1963; Ueyanagi et al., 1970; Nakamura and Rivas, 1972), and may be somewhat heavier than males of the same length (de Sylva and Davis, 1963).

3.12 Maturity

Ueyanagi et al. (1970) state that the species attains sexual maturity at a length from orbit to fork of tail of about 130 cm. The relationship of age to size of white marlin is not known.

3.13 Mating

The only reference we have found to mating of white marlin is by Hemingway (1935, not seen by us, but quoted by LaMonte and Marcy, 1941). He reports paired breeding in the current off Cuba in May.

3.14 Fertilization

Fertilization is external. Eggs and sperm are probably discharged separately by adjacent fish and come together in the ambient water.

3.15 Gonads

White marlin gonads consist of two sausage-shaped organs tapering at both ends which lie ventral to each side of the stomach. The ovary is yellowish to orange red, circular in cross section and often covered with thick layers of connective tissue whereas the testis is white to pinkish, triangular in cross section, and is lobular in appearance, without connective tissue covering (LaMonte, 1958b).

LaMonte (1958b) found that in one male the gonads were about 280 mm in length and 80 mm in circumference and very flabby; but in two others they were the same length but about 170 mm in circumference and very firm. In a male specimen weighing 17.7 kg the gonads measured 178 mm in length and about 38 mm in circumference.

Krumholz (1958) recorded the ratio of gonad weight to body weight for 20 male and 22 female white marlin taken in the Florida Current in late April 1956. The gonads contributed from 0.097 to 1.266% of male body weight with an average of 0.422 and from 0.882 to 9.762% of female body weight with an average of 4.556. The male for which the testes was 1.266% of the body weight was a 36.4-kg fish, the largest examined. The relative weight of gonads was also much greater in large females than in small ones. Since these gonads were not yet ripe, these figures do not indicate the maximum relative weight of the gonads. The average gonad weights, in percent of weight of fish by 10-pound (4.5-kg) groups (Krumholz, 1958), were as follows:

	Weight	*Number of fish*	*Gonads*
Male:	20-29	2	0.216
	30-39	5	0.224
	40-49	3	0.360
	50-59	6	0.451
	60-69	2	0.750
	70-79	1	0.333
	80-89	1	1.266

	Weight	*Number of fish*	*Gonads*
Female:	50-59	3	1.521
	60-69	7	2.641
	70-79	5	5.007
	80-89	6	5.467
	90-99	1	8.338

Ueyanagi et al. (1970, Fig. 27) showed that the percentage group maturity of female white marlin caught in the area east of Brazil in November-March increased with size of fish.

No information on the fecundity or number of eggs produced in a year was found.

There is no direct information on the number of broods produced during a lifetime, but two white marlin tagged as adults have been recaptured about 6 yr after their release [unpublished WHOI (Woods Hole Oceanographic Institution) data]. This indicates that a white marlin might spawn at least six times in its lifetime.

No information was found on variation in fecundity with health or condition, or on correlation between the number of spawn or young produced and the nature of the environment.

3.16 Spawning

The available information indicates that white marlin spawn once a year (de Sylva and Davis, 1963; Hayasi et al., 1970; Ueyanagi et al., 1970). Knowledge of spawning seasons, areas, and behavior is incomplete, because of difficulties in identifying larvae, and the lack of continuous and comprehensive gonad studies. The known distribution of larvae and juveniles is described in 2.21. Ueyanagi et al. state that spawning occurs in subtropical waters and is at its peak in early summer. In their plot of percentage group maturity of female white marlin by areas and quarters of the year, Ueyanagi et al. (1970, Fig. 20) show that the only area in the South Atlantic with a concentration of maturing fish is the one between lat. 20°S and 30°S and long. 20°W and the South American coast. In the fourth quarter of the year, 77% of 51 fish examined in the part of this area west of long. 40°W and 95% of 736 examined in the part east of that meridian were maturing. In the first quarter, 89% of those examined in both parts of the area (94 in the west and 77 in the east) were maturing. Their studies of maturity of females in the area east of Brazil showed a decrease in the number of maturing fish and an increase in the number of spawned-out fish from November through January (Ueyanagi et al., 1970, Fig. 23). Hayasi et al. (1970) note that the rise in hooking rate off southern Brazil in November-April is associated with the appearance of large fish, presumably spawners, in the area, and that the accuracy of this assumption was demonstrated by the appearance of postlarvae and juveniles in the area. They also state that the white marlin taken west of long. 25°W were spawners, whereas those taken east of there were feeding fish.

The same authors mention that white marlin caught in the Caribbean in winter had underdeveloped gonads, but that adults with matured gonads were caught in the northern Caribbean in April-June. These findings are in accord with Erdman's (1956) statements that the ovaries of white marlin taken off Puerto Rico were enlarged in April and that the best formed eggs he had seen were in a fish taken there on 9 June. They also fit with de Sylva and Davis' (1963) report of nearly ripe females in the eastern Straits of Florida in March and May and Krumholz's (1958) finding of nearly ripe males in the same area in late April. De Sylva and Davis found that the ovaries of females taken off Cape Hatteras in June and off Maryland and southern New Jersey in summer were in postspawning or resting condition, although many of the males were still ripe. It is generally believed that summer concentrations of white marlin in the Gulf of Mexico and between Cape Hatteras and Cape Cod are of spent fish which are intent on feeding. These findings suggest that spawning in the western North Atlantic occurs almost entirely in spring, in the areas noted here and under 2.21.

The spawning period and areas coincide at least in part, with those of the western Atlantic bluefin tuna, *Thunnus thynnus thynnus* (Rivas, 1955; Potthoff and Richards, 1970). The young of this species share their summering area between Cape Hatteras and Cape Cod with the white marlin.

The spawning areas of white marlin are in deep and blue oceanic waters with generally high surface temperatures (20°-29°C, except in the Atlantic southern gyrals, reg. 5.9.1), and high surface salinities (>35‰). Except off Cabo Frio, Brazil, the productivity of these waters is considered to be low.

Nothing was found in the literature about the variations of spawning grounds.

Little is known of the ratios and distribution of sexes on the spawning grounds. Ueyanagi et al. (1970) found 2,037 males and 1,051 females in the area between lat. 5°S and 30°S, and long. 15°W and the coast of South America, during November-April. This area includes the South Atlantic spawning ground described above (lat. 20°S-30°S, long. 20°W to the coast), and the period coincides with the spawning season as indicated by Hayasi et al. (1970). In late April, Krumholz (1958) found 20 males and 22 females in the eastern Straits of Florida.

Hemingway (1935) described the breeding of white marlin as follows: "White marlins breed off Cuba in May. They breed in the same way that the grouper does, except that as they are a fish of the current, they breed in the current instead of on the reef. The female marlin heads into the current while the male heads in the opposite direction, and while they are side by side the female expels the eggs and the male the milt; the

male then catches the eggs in the basket-like opening of his gill covers and lets them pass out through his mouth." LaMonte and Marcy (1941) question the feasibility and utility of the latter operation, but the observation of paired spawning may nonetheless be basically accurate.

3.17 Spawn

White marlin eggs have yet to be accurately identified according to Morrow (1965), but are free-floating in the water column. De Sylva and Davis (1963) assume that ripe eggs would appear translucent.

3.2 Preadult Phase

3.21 Embryonic phase

Embryonic development of the white marlin has not been observed and information concerning this phase of life is not available.

3.22 Larvae phase

Other than observations made on planktonic samples of larval white marlin, little is known about their development and activities during this stage of life. The larval white marlin has heavy, pointed opercular spines and lacks the characteristic long bill of the adult (Scotton and de Sylva, 1972) (Fig. 8).

The postlarvae of white marlin are also rare. De Sylva (1963) gives a detailed description of a 125-mm specimen collected off Wilmington, N.C. This fish is notable in that it bears a saillike dorsal fin with four distinct ocelli near the base. A second very similar specimen (191 mm in total length) was taken off the northwest coast of Cuba (Anon., 1968).

Information on the behavior and continuous development during this period in the life cycle, however, is not available.

3.23 Adolescent phase

No material in the range between these postlarvae and the 904-mm and 964-mm specimens mentioned in 1.31 are available. As noted above, the latter specimens have attained all the adult characteristics except that the middle of the first dorsal fin is somewhat higher, the pectorals very slightly shorter, and the pelvics longer than in adults. Maturity occurs at a length (from eye to fork of tail) of about 130 cm (145-cm body length) (Ueyanagi et al., 1970). This is equivalent to a weight of about 37 pounds (17 kg) for females and 31 pounds (14 kg) for males (de Sylva and Davis, 1963). These authors and Nakamura and Rivas (1972) indicate that very few smaller (immature) white marlin are taken in the U.S. sport fisheries. Ueyanagi et al. (1970), however, show that many white marlin in this immature size range are taken by the Japanese longline fishery in equatorial waters lat. 10°S to 10°N, and north of lat. 10°N in May-October. Most of the small fish taken from lat. 10°S to 30°N are males. Most of the available biometric data, however, are from mature fish.

Figure 8.—Baby white marlin, about ⅛ inch (3.2 mm) long, with heavy, pointed spines and lacking the characteristic bill. (Drawing by Joy Godfrey Alexander, from Scotton and de Sylva, 1972, Figure p. 200.)

3.3 Adult Phase

3.31 Longevity

Weight frequency distributions and tag returns suggest that the white marlin may be longer lived than was once believed. Each of two weight frequency polygons for fish taken off Maryland and southern New Jersey (de Sylva and Davis, 1963, Figs. 4, 5) show several peaks. If these peaks actually represent year classes, as they seem to, this is a good indication of longevity. In addition several tagged white marlin have been recaptured after over 4 yr at large (Mather et al., 1974) including two recent recaptures of fish which had been out over 71 mo (unpublished WHOI data). Since these fish were not remarkably small when tagged, the life span must sometimes exceed 6 yr.

3.32 Hardiness

White marlin seem to be of a reasonably hardy nature. Mortality rates for fish which had been subjected to the rigors of capture on hook and line and tagging and had been at large for from less than 1 mo to more than 48 were 30% per year with 95% confidence limits of 23% and 36% and a coefficient of instantaneous total mortality of 0.36 ± 0.10 (Mather et al., 1974).

These fish do seem, however, to be somewhat temperature sensitive. Earle (1940) reported that in the Ocean City, Md. fishery, white marlin vanished after a sudden drop in water temperature of a few degrees and returned when water temperature returned to normal.

There is no information on survival of white marlin in confined environments, or on variations in hardiness with age, size, or physiological states.

Table 2.—Trophic relationships between epipelagic predatory fishes of the tropical waters.

Main group of predators	1	2	3	4	5	6	7
1. Small tuna (*K. pelamis*, young *Thunnus* sp.)	-	E, C	E,(C)	C	V, C	(V)	E
2. Large tuna (*Thunnus* sp.) and small marlins (*Tetrapturus* sp.)	V, (C)	-	E, (C)	(V)	V	V, C	E, C
3. Large marlins (*Makaira* sp.) and swordfish (*Xiphius gladius*)	V, (C)	V, (C)	-	(V)	V	V	C, E
4. *Coryphaena* sp.	C	(E)	(E)	-	C	-	(E)
5. Snake mackerel (*Gempylus serpens*)	E, C	E	E	C	-	E	(E)
6. Lancetfishes (*Alepisaurus* sp.)	(E)	E, C	E	-	V	-	E
7. Sharks	V	V, C	C, L	(V)	(V)	V	-

NOTE: Reading across the table, the relationships between each group of predators are seen (C - competitor; E - enemy; V - victim). The groups are numbered uniformly in the rows and columns.
Source: Parin, 1968, Table 13.

3.33 Competitors

White marlin compete with the tunas, large marlins, sharks, and to some degree with lancetfishes and are victimized by larger billfish and sharks (Parin, 1968) (Table 2).

Fox (1971) indicates from the Japanese longline data that white marlin distributions overlap strongly with those of yellowfin tuna, *Thunnus albacares*, and blue marlin, *Makaira nigricans*. Wise and Davis (1973) show that during certain seasons of the year centers of white marlin abundance coincide with those of blue marlin and sailfish, *Istiophorus platypterus*, abundance. During the summer, adult white marlin and small (2-50 kg) bluefin tuna, are both abundant off the U.S. coast between Cape Hatteras and Cape Cod (Farrington, 1949a). Since both of these fishes feed largely on small schooling fishes and squid, they must compete with each other considerably.

3.34 Predators

Very little is known about the predation on white marlin. It must be presumed that members of the shark families prey on this species at one time or another. When fighting white marlin on rod and reel the senior author has noted the presence of mako sharks, *Isurus oxyrinchus*. No documented evidence of actual attacks on white marlin are available however, although Poey (1861) described marlin on a fisherman's line as becoming furious at the approach of its natural enemy the shark and receiving frightful wounds from its adversary.

Maéda (1967) observed the killer whale, *Orcinus orca*, attacking marlin but added that such instances were probably rare since meetings of the two species were most likely infrequent.

3.35 Parasites, diseases, injuries, and abnormalities

Parasites and diseases: Records of parasite infestation and disease problems in white marlin are minimal. Although both problems are likely to occur in this species, few exact classifications of them have been made.

Nikolayeva and Ezpeleta (1966) examined four white marlin from the Gulf of Mexico and found from 597 to 6,833 specimens of parasites per fish. Of the fish examined, all had members of the parasite groups Cestoidea, Trematoda, Nematoda, and Crustacea; three had members of Monogenoidea; and only one had representatives of Sporozoa and Acanthocephala. Silas (1967) and Silas and Ummerkutty (1967) summarized the known species of trematodes, cestodes, and parasitic copepods found in or on white marlin (Table 3). Jones (1971) mentioned reports of crater wounds caused by the squaloid shark, *Isistius brasiliensis*, on various species of marlins.

Injuries and abnormalities: A common injury to the white marlin is the loss of part or most of its bill. The

Table 3.—Parasites found on white marlin.

Locality	Parasite	Location on host
Monogenetic trematodes (Silas, 1967):		
N.W. Atlantic	*Capsaloides cornuatus* (Verrill)	On body
N.W. Atlantic	*Capsala laevis* (Verrill)	
Cestodes (Silas, 1967):		
N.W. Atlantic	*Bothriocephalus manubriformis* (Linton)	Intestine
Copepods (Silas and Ummerkutty, 1967):		
W. Atlantic	*Gloiopotes ornatus* (Wilson)	On body

exact problems this raises for the white marlin are not known but we have seen hearty, active fish which have been caught with this condition.

3.4 Nutrition and Growth

3.41 Feeding

Most indications given by the degree of digestion of various food items in the stomachs of white marlin show them to be daytime feeders. De Sylva and Davis (1963) found that nearly all round herring, *Etrumeus sadina*, taken from marlin caught between Ocean City, Md., and Atlantic City, N.J., were only slightly digested and appeared quite fresh, indicating recent ingestion (i.e., from 0800 to 1700). At Bimini, Krumholz and de Sylva (1958) likewise observed that some of the fish caught before 1000 still contained bait fish that were only slightly digested, and fish caught at 1130 and 1330 contained a small octopus and a filefish respectively, neither of which was in any advanced stage of decomposition. The marlin may feed at night as well, for squid which showed signs of having been in the stomachs for a considerable period of time were found in fish taken in the morning (de Sylva and Davis, 1963). This does not, however, appear to be the major feeding time.

The general areas of feeding may be of different natures from deep to shallow water and from near the shore to out in the open sea. Nakamura (1971) felt that sargassum lines are attractive as feeding areas for fish in the Gulf. Off Bimini, Krumholz and de Sylva (1958) inferred that the marlins are not primarily surface feeders but that they probably obtain a large portion of their food at depths as great as several hundred feet.

The method used by the white marlin for capture of prey is not certain. Earle (1940) reported that they kill or stun their food by spearing it or hitting it with their bill. This may not always be true, however, as whole specimens found in the stomach have been unscathed. In such cases the marlin may have simply overtaken the prey.

3.42 Food

Squid, it seems, play one of the most important parts as food of the white marlin in the different areas of its abundance. Erdman (1958) examined seven fish and found squid in four marlins, snake mackerel in two, doctorfish in two, filefish in one, triggerfish in one, and one each of a blue runner, young tuna, and *Brama* in Puerto Rican samples. In the Bahamas, he examined eight and found five with squid, four with *Pseudoscopelus*, five with snake mackerels and one each with octopods, doctorfish, bigeyes, and round robins (*Selar* sp. or *Decapturus* sp.). Krumholz and de Sylva (1958) also working in the Bahamas, found food in nine of 50 stomachs examined, including three with squid, three with octopods, two with unidentifiable fish remains, and one each with a crab, filefish, and balao.

In the Gulf of Mexico, Nakamura (1971) and Nakamura and Rivas (1972) found that the most consistently important food items of the white marlin from 1966 to 1971 were squid, dolphin, *Coryphaena hippurus*, and hardtail jacks, *Caranx crysos*. Mackerel were next in importance and flying fish and bonito also played a big part. Other items found were cutlassfish, swellfish, herring, barracuda, moonfish, triggerfish, remora, hammerhead sharks, and crabs but to a much lesser and more inconsistent degree.

Along the middle Atlantic coast the favorite food items for the white marlin appear to be the round herring and squid, *Loligo pealei* (de Sylva and Davis, 1963). Carangids were also well represented in addition to several other species as shown in Table 4 by number of times occuring.

This same area was studied by Wallace and Wallace (1942) (not seen by us; quoted by de Sylva

Table 4.—Frequency of occurrence of different organisms in stomachs of 55 white marlin, *Tetrapturus albidus*, taken by anglers between Ocean City, Md., and Atlantic City, N. J., 29 July to 12 September 1959, and in 18 white marlin taken at Atlantic City, 3 to 5 August 1960.

	Number of times occurring	
	1959	1960
VERTEBRATES		
Fishes		
Clupeiformes (unidentified)	1	
Clupeidae (Dussumieriinae)		
Atlantic round herring, *Etrumeus sadina*	22	1
Hemiramphidae		
Halfbeak, *Hyporpamphus unifasciatus*[1]	2	1
Carangidae		
Banded rudderfish, *Seriola zonata*	4	1
Round scad, *Decapterus punctatus*	1	1
Jack, *Caranx* sp.	1	4
Unidentified carangids	3	
Scombridae		
Mackerel, *Scomber* sp.	2	
Xiphiidae		
Swordfish, *Xiphias gladius*		1
Dactylopteridae		
Flying gurnard, *Dactylopterus volitans*	1	
Fish remains (unidentified)	9	
INVERTEBRATES		
Mollusca (Cephalopoda)		
Squid, *Loligo pealei*	13	2
OTHER		
Rockweed, *Fucus* sp.		1
EMPTY	10	4

[1]Not a bait.
Source: de Sylva and Davis, 1963, Table 5.

and Davis 1963), with similar results as far as prey species and relative abundance are concerned. They also found, however, dolphin, sand lances, *Ammodytes tobianus*, and anchovies, *Anchoa browni*.

3.43 Growth rate

Ages of white marlin have not been determined, but some estimates of growth in time intervals have been attempted. De Sylva and Davis (1963, Figs. 1-5) presented histograms of size frequencies for white marlin caught in various years and in different areas in the western North Atlantic. They believe that these fish school according to size and return to certain fishing areas in these groups. A strong year class apparently occurred from 1957 to 1959 at Ocean City, Md., peaking at 20 kg in 1957, 24.1 kg in 1958, and 28.6 kg in 1959. The difference between the modal sizes in consecutive years presumably represents the annual growth for these hypothetical year classes.

Nakamura (1971) calculated the constants a and b in the equation, $W = a\,L^b$ (W = weight in pounds and L = total length in inches), describing the length-weight relationships for white marlin taken in the Gulf of Mexico. He presented the length-weight-girth calculations for fish from 70 to 110 inches (177.8 to 279.4 cm) in total length which resulted from the measurements taken on 162 individuals ranging from 75 to 100 inches (195.6 to 254 cm) in total length (Table 5).

3.44 Metabolism

Metabolic rates of the white marlin have not been determined.

3.5 Behavior

3.51 Migrations and local movements

Seasonal changes in distribution led to suppositions about the migrations of white marlin, but tagging has provided more positive information. In the first tagging efforts at Ocean City, Md., in the summer of 1939, Earle (1940) marked 84 white marlin, but none of these tags were returned. Tagging by the Cooperative Game Fish Tagging Program of the Woods Hole Oceanographic Institution, U.S.A., (Mather, 1960; Mather et al., 1972; Mather et al., 1974) has produced considerable insights into the movements of white marlin in the western North Atlantic. As of

Table 5.—Calculated weights and girths for white marlin, 70-110 inches total length, based on 162 specimens, New Orleans Big Game Fishing Club, 1966, 1968, 1970, with size range and constants shown.

Total length (inches)	Weight (pounds)	Girth (inches)
70	23	19.3
72	25½	19.8
74	28½	20.5
76	31½	21.1
78	35½	21.7
80	39	22.3
82	43	22.9
84	47	23.5
86	51½	24.1
88	56½	24.7
90	62	25.4
92	67½	26.0
94	73½	26.6
96	79½	27.2
98	86	27.9
100	93½	28.5
102	101½	29.2
104	109	29.8
106	117	30.4
108	126	31.0
110	135½	31.6

Size range			Weight constants		Girth constants	
Total length (inches)	Weight (pounds)	Girth (inches)	Log (a)	b	Log (a^1)	b^1
75-100	29-100	20-32	-5.85911	3.91484	-0.73896	1.09713

Source: Nakamura, 1971, Tables 27 and 29.

January 1973, some 9,000 of these fish had been marked in that area, and 144 tags had been returned.

The times of arrival in the various fishing grounds, and observations of the behavior of the fish themselves (Farrington, 1937) indicate that the white marlin which concentrate in summer in the Cape Hatteras-Cape Cod area first enter its southern portions then move northward and eastward along the coast as the season advances. Tag returns (Mather et al., 1974, Fig. 2), however, show that the fish may move in various directions within this area during the summer. The fish leave these waters and move eastward (Fig. 9), sometimes as far as long. 40°W, in September and October. In late fall and winter, they gather off the northern coast of South America, from the Guianas to Colombia. In spring they migrate northward, some passing through the Yucatan Channel and the Straits of Florida, others through the other Passages of the Greater Antilles, and still others moving northward with the Antilles Current east of the West Indies and the Bahamas. Their migration from around the Bahamas back to their summering

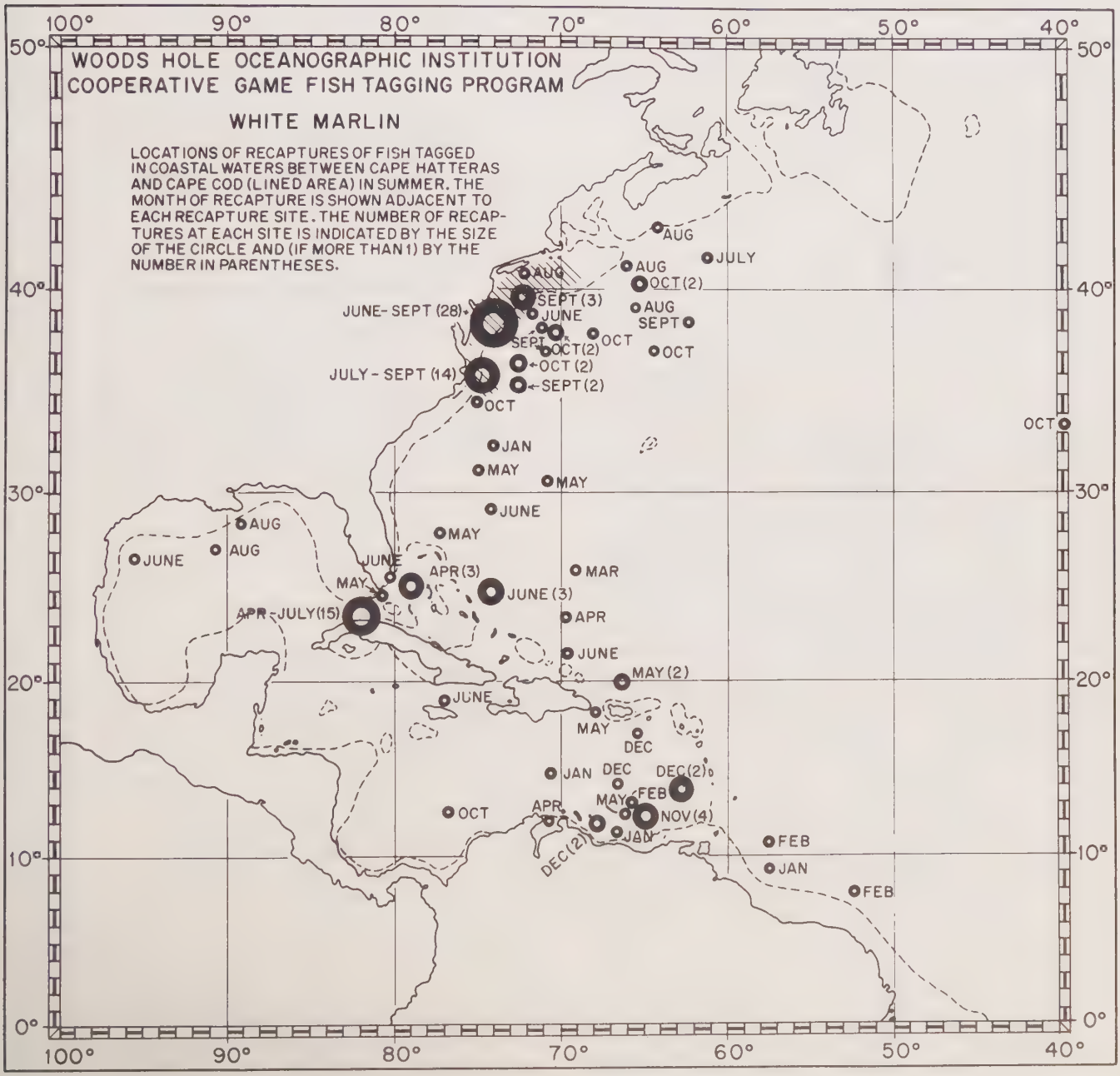

Figure 9.—Tag returns from white marlin released in coastal waters between Cape Hatteras, N.C. and Cape Cod, Mass.

area apparently passes well east of the American coast. Fewer than 5% of the 124 returns from fish tagged in the Cape Hatteras-Cape Cod area show substantial deviations from this pattern. The release and recapture data for one fish released off Venezuela in the fall and three released among the Bahamas in spring (Fig. 10) also fit with the above pattern.

Results (Fig. 10) from tagging two groups of white marlin, presumably different from each other and from the one just discussed, which concentrate in the northern Gulf of Mexico in summer and off Venezuela in late summer and early fall, respectively, are less clear-cut. Seasonal interchanges between the Gulf of Mexico in the warm season and the Straits of Florida and the adjacent Bahamas in the cold season have been demonstrated, but fish marked in the latter area have also been recaptured in the northern Caribbean and well east of Brazil. Individuals marked off La Guaira, Venezuela, in August-September have been recaptured off the Guianas in November-December, but also in the release area in November and January. The monthly distribution of longline catches indicates

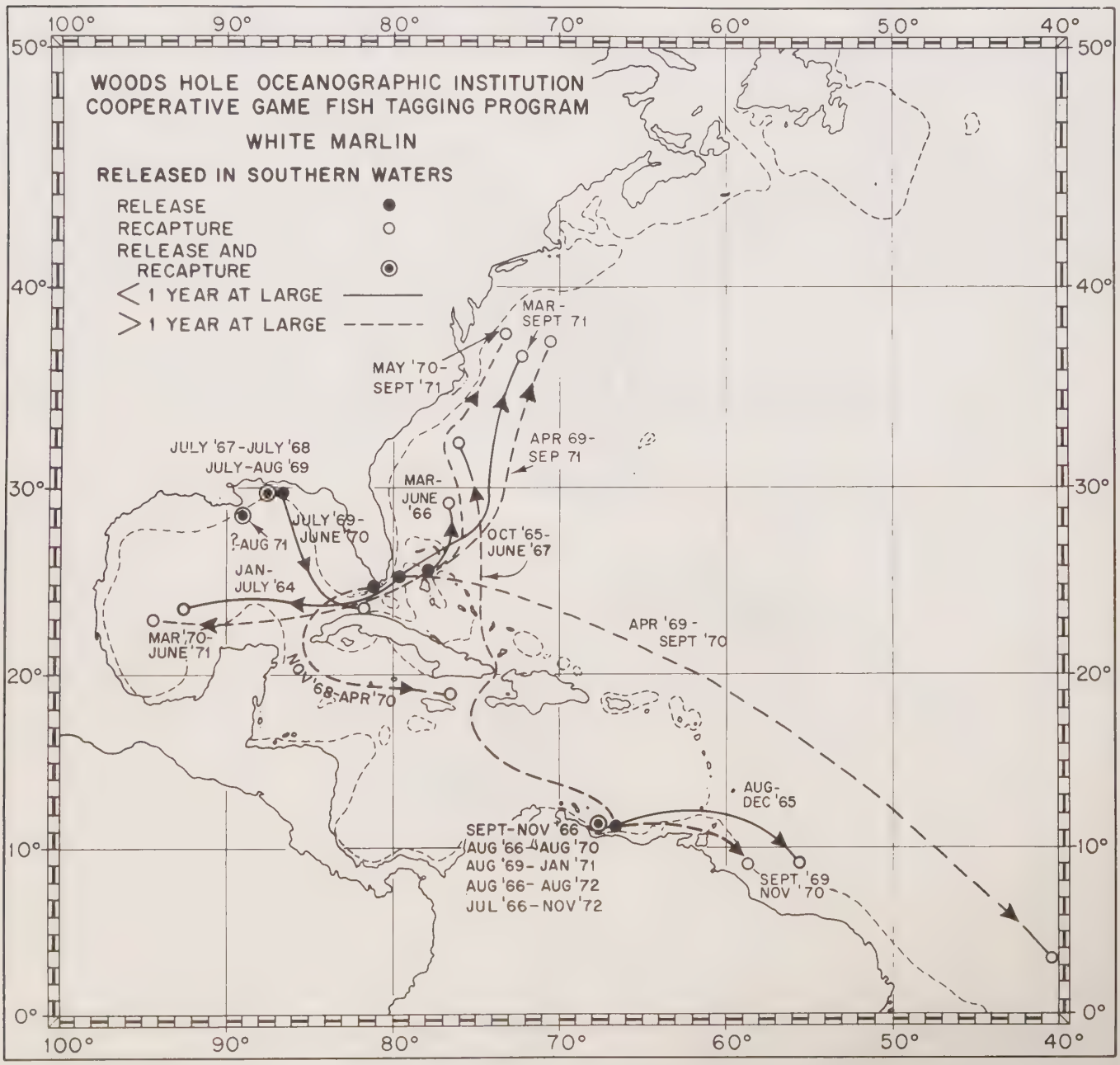

Figure 10.—Tag returns from white marlin released in waters south of lat. 32°N. (Migration routes are diagrammatic.)

that a group of white marlin winters off Venezuela and summers in the Gulf of Mexico (Mather et al., 1972). The distribution of the group which summers off the middle Atlantic coast of the United States coincides in winter (off northern South America) with that of white marlin which summer off Venezuela and in the Gulf of Mexico, and in spring (in the Straits of Florida) with other fish which summer in the Gulf of Mexico. Thus interchanges between these groups, such as have been indicated by a few tag returns, are probable.

The fact that not one of the white marlin tagged in the western North Atlantic has been recaptured in other areas, and the low longline catch rates in the equatorial area (Ueyanagi et al., 1970; Hayasi et al., 1970; Mather et al., 1972), as well as the widely separated spawning areas (see 3.16), indicate that the marlin stocks of the North and South Atlantic are distinct. The lack of tag returns showing migrations from the western to the eastern North Atlantic is less conclusive as an indication of stock separation, since the longline and sport fishing efforts in the latter area are slight.

Robins (1974) cites Ueyanagi et al. (1970, appendix, Figs. 2j, k, l) as an indication that the white marlin which concentrate off Gibraltar in late summer may move progressively south along the coast of Africa in the fall to about lat. 5°N.

The monthly distribution of longline catches in the South Atlantic (Fig. 5) shows a heavy concentration of white marlin off Brazil in September-February and a lesser one off western Africa in June-July, with considerable areas of high catch rate in various mid-ocean areas in July and October-February (Hayasi et al., 1970; Mather et al., 1972), but it is not certain that these occurrences represent the migrations of a single group of fish.

Most fish migrations relate to spawning or feeding. The summer concentrations of white marlin in the North Atlantic (Venezuela, Gulf of Mexico, Cape Hatteras-Cape Cod area, and off Gibraltar) are for feeding (see 2.3), and occur in areas which are highly productive, at least in comparison with the surrounding waters. The spring concentration in the vicinity of the Greater Antilles, the Bahamas, and Florida is for spawning (see 2.3 and 3.16). Tagging has shown that one group of white marlin migrates from a summer feeding area (Cape Hatteras-Cape Cod) eastward and southward to a wintering area (off northern South America) whose attractive properties are not known, then northward to a spring spawning area (Greater Antilles-Bahamas) and thence further north to the summering area. Tagging also indicates that another group of white marlin may migrate from a summer feeding ground in the Gulf of Mexico to winter among the northwestern Bahamas, spawn in spring in the Bahamas-Cuba area, and return to summer in the Gulf. The group, which, on the basis of longline catch distribution (Mather et al., 1972), appears to summer in the Gulf and winter in the southeastern Caribbean, may also spawn in spring near the Greater Antilles.

In the South Atlantic, the summer concentration off southern Brazil is for spawning (see 2.3 and 3.16). It appears that the marlins move to this area from off northeastern Brazil in October-November and disperse northward in March-May (Hayasi et al., 1970). These authors also note a feeding concentration of large females off Africa around lat. 10°S from June through August.

3.52 Schooling

Generally not considered a schooling fish, white marlin are most often seen as individuals or in pairs "tailing" with only the dorsal lobe of their caudal fins showing. Small schools (5-12 fish), however, are occasionally seen feeding on schools of bait, or tailing, but loose aggregations of numerous fish scattered over fairly large areas are more typical.

At some point in their life cycle the white marlin may come together in schools. De Sylva and Davis (1963) proposed that they may school according to size or sex at various seasons of the year. Little concrete evidence is available, however, for determining the extent of time a school may remain together or the size such schools may attain.

3.53 Responses to stimuli

As discussed previously, temperature seems to play a crucial part in the response of white marlin. Their disappearance from the Ocean City fishery during a temperature drop of a few degrees and return in numbers similar to catches before the drop as soon as the temperature returned to normal (Earle, 1940) is one example. Similarly the white marlin arrive along the east coast of the United States during the warm summer season and move offshore and to the southward as fall and cold water approach (Mather et al., 1972). Gibbs (1957) noted the relationships between the distribution of white marlin in the Gulf of Mexico and the 75°F (23.9°C) isotherm (see 2.3).

Hayasi et al. (1970) note that the two separate areas of high hooking rates for white marlin in the North and South Atlantic both shift northward during May-October and southward during November-April. In other words, they both move to higher latitudes as the water warms and to lower latitudes as it cools.

De Sylva and Davis (1963) performed a most exhaustive environmental study of white marlin grounds from Atlantic City, N.J. to Ocean City, Md. They found that temperature, salinity, oxygen content, and plankton volumes all played a role in the presence of the white marlin as explained in 2.3.

If marlin seek certain optimum environmental conditions at one time or another, they may swim in deeper layers when surface conditions are not favorable. In such a case types of fishing gear used will

play a role in determination of their presence. For example, longline gear may be necessary to catch the deeper strata of fish while trolling gear (baits, artificial lures, and teasers) attract those near the surface.

The behavior of white marlin toward trolling baits is very indicative of his intentions according to Jaen (1964). If the fish is pale green and placidly following the bait, he will probably not attack. However, if he is dark-colored and his fins become a shiny bright blue, a reaction known to fishermen as "lighting up," he will strike immediately. The raising of the first dorsal fin is also considered to be an indication of excitement.

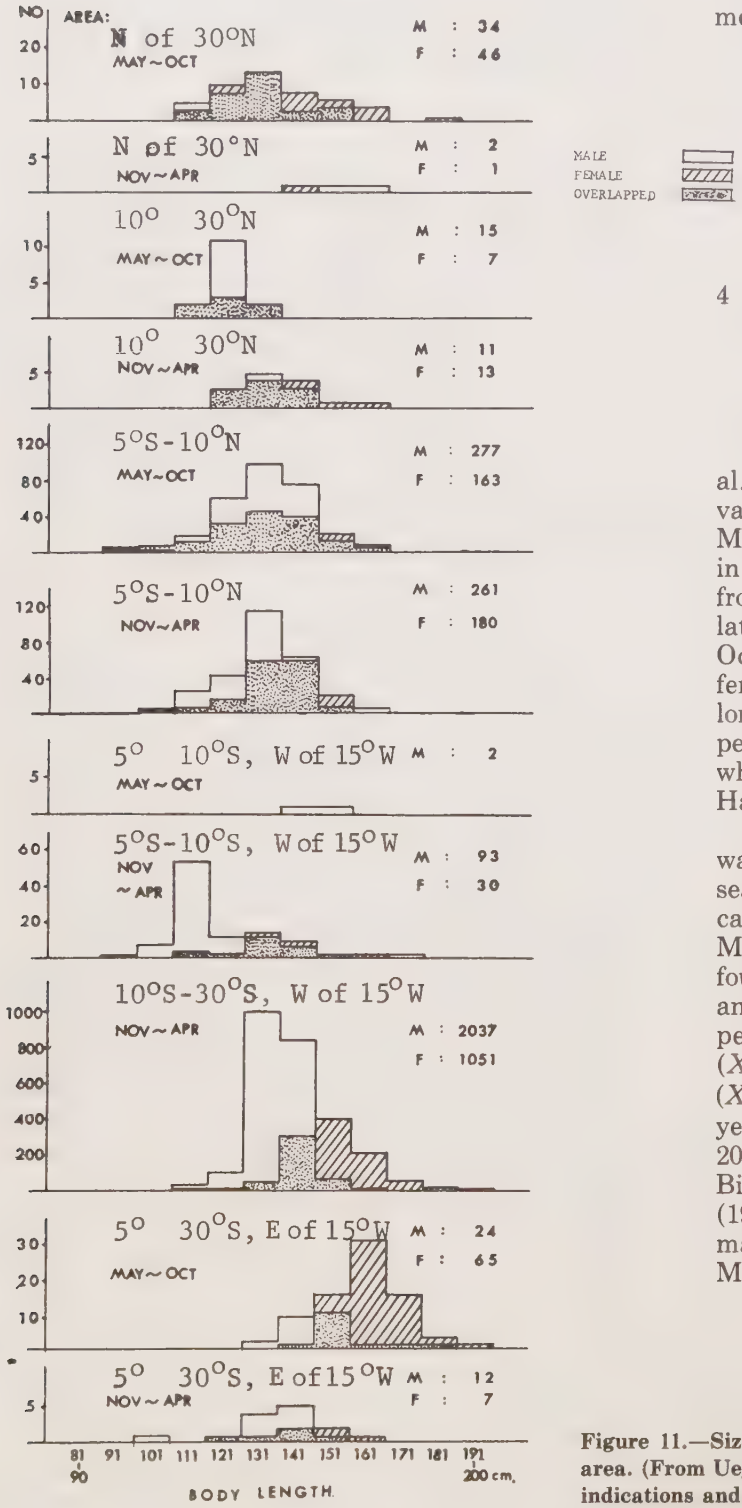

Figure 11.—Size composition of white marlin by season and area. (From Ueyanagi et al., 1970, Fig. 19 and caption.) (Area indications and legend added.)

4 POPULATION

4.1 Structure

4.11 Sex ratio

Extensive sampling of oceanic catches (Ueyanagi et al., 1970) shows that the sex ratio of white marlin varies considerably with season and area (Fig. 11). Males appear to be predominant in most areas except in three cases: north of lat. 30°N in May-October, from lat. 10°N to 30°N in November-April and from lat. 5°S to 30°S, and east of long. 15°W in May-October. The proportion of 2,037 males to 1,051 females in the area from lat. 10°S to 30°S and west of long. 15°W during November-April, the area and period in which the major spawning of South Atlantic white marlin evidently occurs (Ueyanagi et al., 1970; Hayasi et al., 1970), is interesting.

Sex ratios of white marlin collected in inshore waters also varied considerably according to areas and seasons. De Sylva and Davis (1963) examined fish caught between Atlantic City, N.J., and Ocean City, Md., during the summers of 1959 and 1960. They found 17 males and 41 females in 1959, and 50 males and 58 females in 1960. "The deviation from the expected 1:1 ratio is highly significant in 1959 ($X^2 = 6.63$; $P < 0.001$), non-significant in 1960 ($X^2 = 0.44$), and probably significant for the combined years ($X^2 = 5.02$; $P = 0.02$)," Krumholz (1958) found 20 males and 22 females in a sample caught off Bimini, Bahamas, in April 1956. Nakamura and Rivas (1972) reported that females definitely outnumbered males in samples examined at four ports in the Gulf of Mexico during May-October:

	1967 M:F	1968 M:F	1969 M:F	1970 M:F	1971 M:F
South Pass, La.	20:46	15:59	4:25	4:16	3:12
Pensacola, Fla.					2:16
Panama City, Fla.					7:13
Destin, Fla.					19:91

Jaen (1964), however, stated that the majority of the white marlin taken off Venezuela, mainly in August-October, were males.

4.12 Age composition

No age determinations were found in the literature.

4.13 Size composition

The length composition of the white marlin population as a whole is best illustrated by Figure 11, which shows the length frequencies for samples of longline catches in various seasons and oceanic areas.

De Sylva and Davis (1963, Figs. 1-5) present weight frequencies for white marlin caught in the sport fisheries off Ocean City in 1940, 1941, and 1945-59; off Atlantic City in 1958 and 1959; between Ocean City and Atlantic City in 1959 and 1960; off Puerto Rico in 1950-57; and off the Bahamas in 1956. They state that if these marlin belong to the same population, it seems that marlin may school together according to size or sex at various seasons.

The maximum documented size which we have found for white marlin was 161 pounds (73.2 kg) and 8 feet 8 inches (264 cm)—the present world record rod and reel catch from off Miami Beach, Fla., in 1938 (Anon., 1972a).

We found no information on the density of size groups, beyond the size composition data and catch rates shown above.

De Sylva and Davis (1963) showed that, at small sizes [less than 68 inches (173 cm) fork length] female white marlin tended to be heavier than males of the same length (Fig. 12), according to the length-weight formula (see 3.43):

$$\text{Males: } W = 6.0 \times 10^{-4} L^{3.6}$$
$$\text{Females: } W = 4.6 \times 10^{-3} L^{3.0}$$

The constants were derived from measurements of postspawning fish taken from June through September between Atlantic City and Ocean City.

4.2 Abundance and Density (of Population)

4.21 Average abundance

Since no estimates of population size are available, the actual average abundance is unknown.

4.22 Changes in abundance

Local changes in abundance caused by hydrographic conditions were discussed in 2.3.

The apparent relative abundance of white marlin, as indicated by catch rates of the Japanese longline fishery in 1958-66 (Ueyanagi et al., 1970, Fig. 26), declined slightly after reaching a peak in 1962. More recent information (Table 6), however, shows that this net downward trend has continued through 1970, resulting in a decline from a maximum of 2.06 fish per 1,000 hooks in 1962 to 0.80 fish per 1,000 hooks in 1970. Important declines have occurred in the areas (Fig. 13) in which the largest catches were taken: from 4.34 in 1962 to 1.86 in 1970 in BAH; from 10.77 in 1967 to 1.20 in 1970 in RIO; from 2.31 in 1966 to 1.00 in 1970 in NOW; and from 2.44 in 1966 to 0.62 in 1970 in GUI. S. Ueyanagi (pers. commun.) has stated that the average size of the white marlin taken in the fishery has also declined with the catch rates. This is an additional indication that the fisheries have actually caused a decline in the abundance of the white marlin stocks.

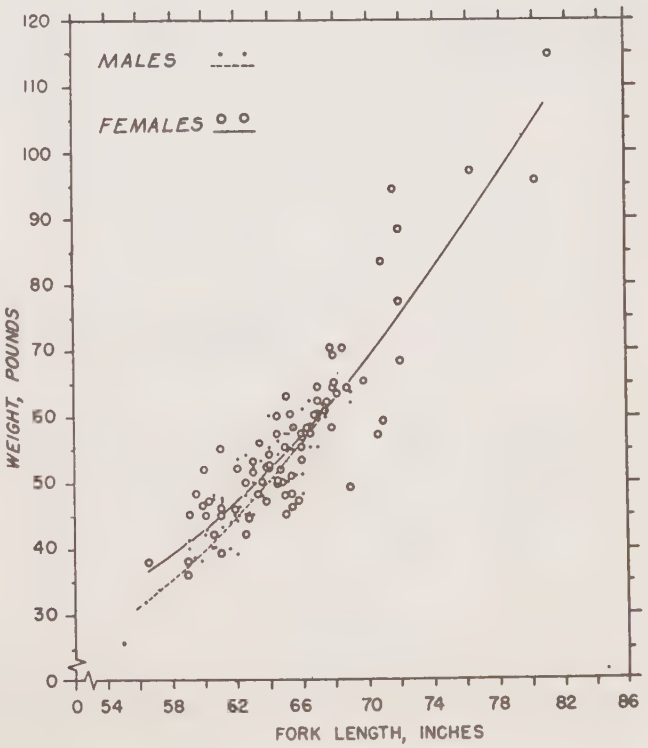

Figure 12.—Length-weight relationship of white marlin, *Tetrapturus albidus*, caught between Atlantic City, N.J. and Ocean City, Md., July-September 1959 and 1960. Males are represented by dotted line and closed circles; females are represented by solid line and open circles. (From de Sylva and Davis, 1963, Fig. 6 and caption.)

Table 6.—Catch rates (numbers of fish/1,000 hooks) for white marlin of the Japanese Atlantic longline fishery, 1956-70, by years and areas. Note: 0.00 =<0.005 but>0; 0 = effort but no catch; - = no effort. Data furnished by J. P. Wise (pers. commun.). See Figure 13 for areas.

Year	GM	NOW	NOE	CAR	GUI	CV	GG	BAH	BEN	RIO	Total
1956	-	-	-	-	0.04	-	-	0	-	-	0.04
1957	0	-	-	0	0.57	0.24	0.05	0	-	-	0.25
1958	-	-	-	0	0.19	0.31	0.01	0.15	-	-	0.17
1959	-	0	0	0.24	0.13	0.35	0.09	1.73	0	3.00	0.44
1960	-	0	0.09	0.06	0.33	0.09	0.03	2.06	2.70	0	0.55
1961	-	0.40	0.11	0.43	0.70	0.26	0.70	4.24	2.21	0	1.43
1962	-	0.66	3.37	3.49	1.10	0.61	1.13	4.34	3.40	2.50	2.06
1963	1.90	1.55	1.05	2.00	1.11	0.85	0.25	4.09	2.91	1.99	1.58
1964	3.63	2.10	0.65	2.94	1.32	0.78	0.20	2.75	0.64	7.29	1.93
1965	8.02	1.66	0.41	2.07	1.35	0.77	0.08	3.86	0.35	6.22	1.33
1966	5.02	2.31	0.40	5.10	2.44	0.59	0.05	2.58	0.21	4.72	1.66
1967	4.50	1.06	0.23	6.44	0.94	0.63	0.08	2.46	0.34	10.77	1.37
1968	2.29	1.23	0.05	3.68	0.83	0.43	0.08	3.76	0.04	7.19	1.42
1969	3.74	1.64	0.07	5.75	0.90	0.49	0.05	2.92	0.15	1.32	0.91
1970	5.01	1.00	0.41	1.77	0.62	0.32	0.06	1.86	0.03	1.20	0.80
Fish/1,000 hooks	4.14	1.61	0.45	3.33	1.07	0.58	0.30	3.34	0.71	4.33	1.42
N fish × 10^3	26.5	113.7	4.9	56.6	97.3	50.6	26.6	193.9	61.4	154.1	784.6
N hooks × 10^6	6.4	70.8	10.9	17.0	90.8	86.8	89.9	58.1	86.9	35.6	553.1

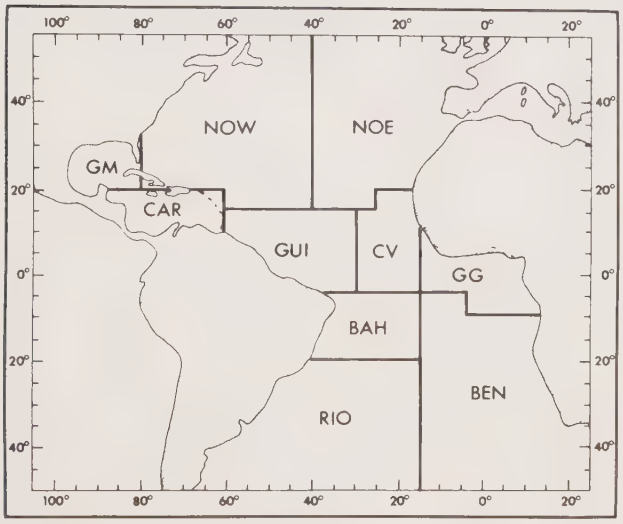

Figure 13.—Division of the Atlantic Ocean. (From Wise and Davis, 1973, Fig. 1 and caption.)

No information was found on the effects of food competition, predation, and natural fluctuations on the abundance of the species.

4.23 Average density

No information was found in the literature.

4.24 Changes in density

Seasonal and areal variations in density, as indicated by longline catch rates, are shown in Figures 4, 5, and 7.

Some indications of seasonal changes in density with depth are given by the relative success of longline and rod and reel fishing, and also by the availability of white marlin to longline fishing in situations in which they are not seen on the surface. Off the U.S. coast between Cape Hatteras and Cape Cod, surface trolling is effective in summer, when white marlin are concentrated on or at the edge of the continental shelf, and longline fishing is poor. In late September and October, the fish have left the shelf (Mather et al., 1972) and longline catches in the adjacent deep waters are at their peak (Fig. 5). A similar situation exists off Venezuela, where surface (sport) fishing is at its peak from August-October, while longline results are relatively poor. Longline fishing, on the other hand, is good in the area in December and February when few white marlin are taken on rod and reel (Fig. 5, for longline catch rates; Jaen, 1964, for sport fishing success).

A generally deeper distribution in oceanic than in coastal waters is indicated by the lack of visual observations of white marlin in deep, oceanic waters, even in areas and seasons in which longline fishing produces good catches.

4.3 Natality and Recruitment

4.31 Reproduction rates

Nothing found in the literature.

4.32 Factors affecting reproduction

Nothing in the literature.

4.33 Recruitment

No information on rates, seasonal patterns, or annual variations of recruitment was found in the literature, nor was any information on the relation of recruitment to stock size and reproductive rates.

The overlapping migratory patterns found for different groups of white marlin (Mather et al., 1972) suggest that some groups may recruit adult fish from others, in addition to their recruitment from spawning.

The length (from orbit to fork of tail) of white marlin at first capture in the Japanese longline fishery varies with season and area (Fig. 11), but is usually in the 90- to 120-cm range. The length (from tip of lower jaw to fork of tail) at first capture in the sport fishery off the middle Atlantic coast of the United States is about 140 cm for males and 155 cm for females (de Sylva and Davis, 1963). Erdman (1956) reported that the smallest white marlin that he had observed at Puerto Rico was 22 pounds (10 kg). Among the white marlin examined by Krumholz (1958) at Bimini, Bahamas, the smallest male was 20 pounds (9 kg) and the smallest female 45 pounds (20 kg). Nakamura and Rivas (1972) reported that the smallest white marlin taken in each of three areas off northwestern Florida in 1971 weighed 31-42 pounds (14-19 kg), and that the smallest taken off South Pass, La., in each year from 1966 weighed 29-39 pounds (13-18 kg).

4.4 Mortality and Morbidity

4.41 Mortality rates

See 3.32.

4.42 Factors causing or affecting mortality

Little is known about the effect of natural factors such as predators, food abundance, and environmental conditions (see 3) on the mortality of the white marlin. The changes in its apparent relative abundance (see 4.22) which have occurred since the development of extensive oceanic longline fisheries, however, indicate that fishing is an important cause of mortality.

4.43 Factors affecting morbidity

See 3.35.

4.44 Relation of morbidity to mortality rates

No information appears in the literature.

4.5 Dynamics of Population (as a Whole)

De Sylva and Davis (1963) studied the dynamics of the Ocean City-Atlantic City sport fishery up until 1960. Assuming similar effort over the years and similar median weights for all fish caught whether boated or released, they found no apparent regular decrease in median weight as the number of marlin caught increased over the years observed. Thus, they concluded there was no reason to believe that angling had affected the stocks.

The present indications that the apparent abundance of the stocks and the average size of the fish taken are decreasing, however, show that studies of the dynamics of the population should be undertaken.

4.6 The Population in the Community and the Ecosystem

As the white marlin is an oceanic species, no specific study has dealt with the ecology of its wide range of distribution. De Sylva and Davis (1963) discuss the relationship of the white marlin with the round herring. On the basis of frequency of round herring in the marlin stomachs, they determined that areas of subsurface plankton concentration may be an important factor of the white marlin community. Squid, too, are a big item in the marlin's diet.

Certain physical features of the oceanic environment are also pointed out by these authors. Salinity, temperature, and oxygen patterns seem to play a role in the location of marlin grounds. Submarine ridges also seem to identify marlin feeding areas. This may be due to an upwelling of plankton attracting the fish and squid on which the marlin feed.

Being members of the holoepipelagic community (Parin, 1968) they perfer the isothermic surface layer of the North subtropical, tropical, and South subtropical regions of the Atlantic and adjacent seas. They reside above the main thermocline but during feeding excursions may pass into its upper horizons.

In the epipelagic environment the white marlin is located on the sixth of seven trophic levels (Fig. 14) beneath only the most powerful and swiftest sharks, *Carcharodon* and makos (Parin, 1968).

Fluctuations in populations occur in a cyclical manner according to the seasonal migration and distribution discussed in 2.

5 EXPLOITATION

5.1 Fishing Equipment

5.11 Gears

The types of fishing gears used for the white marlin vary somewhat from one area to another but all employ the basic hook and line technique. The major classifications are rod and reel, handline, and longline.

In the early days of sport fishing for white marlin the equipment (depending on the experience of the angler) consisted of linen line, varying between 9 and 18 thread (27- to 54-pound [12- to 25-kg] test), a rod with a 6- to 12-ounce (170- to 340-g) split bamboo tip,

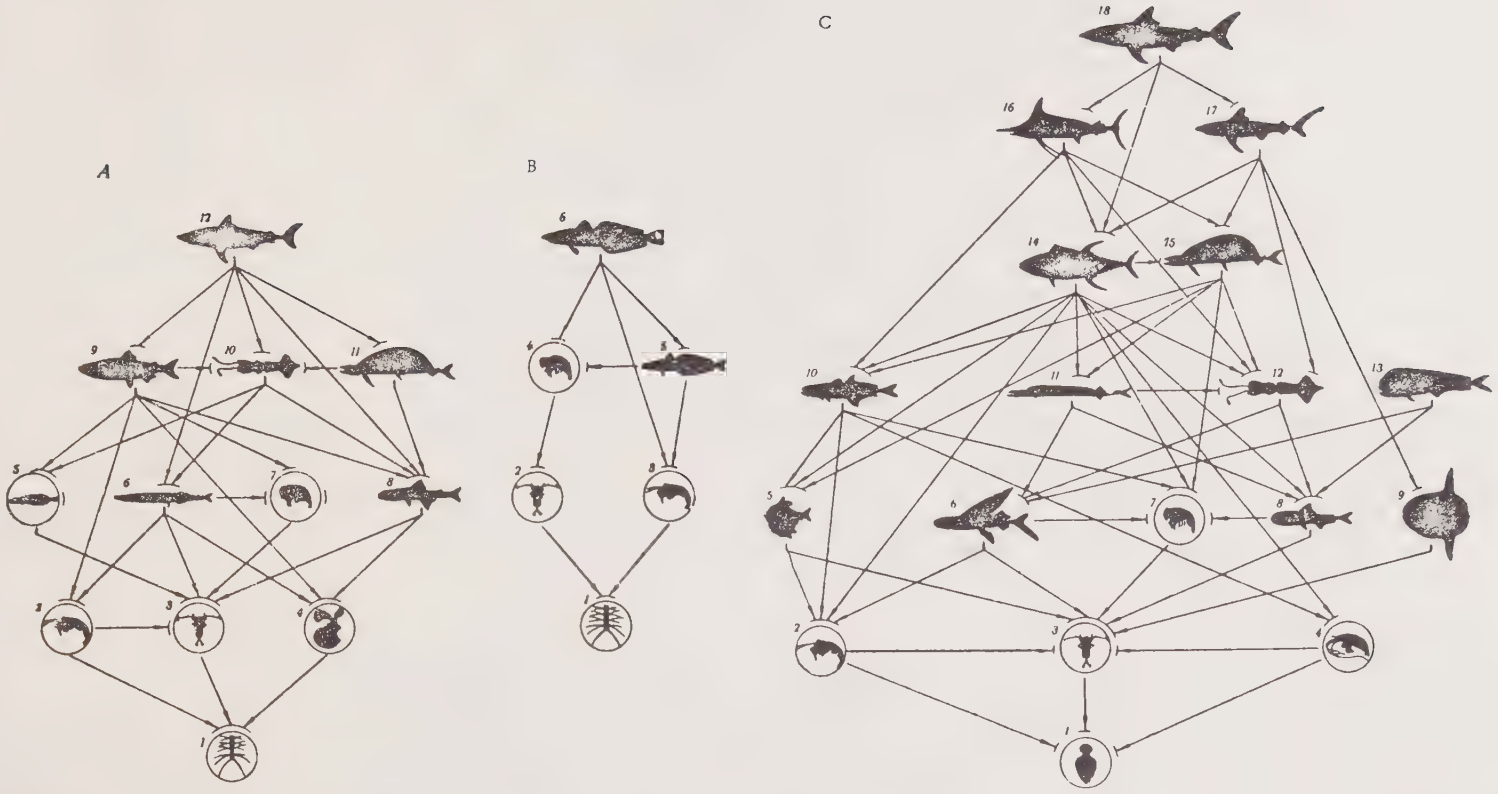

Figure 14.—Diagram of the trophic links among epipelagic fishes (from Parin, 1968, Fig. 49 and caption).

A—subarctic waters; level I—phytoplankton (1); level II—phytophagous zooplankton: euphausiids (2), copepods (3), Pteropoda (4); level III—predatory plankton and planktophagous fishes: fish juveniles (5), saury (6), hyperiids (7), myctophids (8); level IV—nektonic predators: Pacific salmon (9), squid (10), lancetfishes (11); level V—large nektonic predators: mackerel shark (12).

B—antarctic waters: level I—phytoplankton (1); level II—copepods (2), euphausiids (3); level III—hyperiids (4), planktophagous fishes (5); level IV—predatory fishes (6).

C—tropical waters: level I—phytoplankton (1); level II—euphausiids (2), copepods (3), shrimp (4); level III—fishes of the "shifting layers" (5), flyingfishes (6), hyperiids (7), "subsurface" lanternfishes (8), moals (9); level IV—small deepwater ichthyophages (Chiasmodon, etc.) (10), nyctoepipelagic predators (snake mackerel) (11), squid (12), Corphaena (13); level V—tuna (14), lancetfishes (15); level VI—marlins (16), medium-sized sharks (17); level VII—large sharks (18).

and a 4/0- or 6/0-star drag reel (Farrington, 1937). The standard hooks were 7/0 or 8/0. Today's equipment permits greater enjoyment through the use of lighter tackle. Experienced anglers usually use 20- or 30-pound (9- or 14-kg) test synthetic (nylon monofilament or braided dacron) line and a 2½/0, 4/0, or 6/0 reel. The more expensive modern reels with lever drag controls are preferred, but the older and less costly star drag type is still adequate. Leaders are at least 3 m long and of about 60- to 100-pound (27- to 45-kg) test. They may consist of nylon monofilament, stainless steel wire, or nylon coated stainless steel cable. A combination of long length of monofilament or coated cable followed by a short length of wire or coated cable ("Venezuelan rig") is very popular. There is also a trend toward using smaller hooks.

Surface trolling baits for white marlin take on many forms (Brooks, 1968). Squid is generally regarded as the best bait off Ocean City with balao, mullet (15-18 cm in length), eels and strip baits cut from fish also being used. Balao and mullet are the most popular in southern waters. White marlin will also hit artificial lures such as squids, feathers, pork rind strips, cedar and bone jigs, and spoons.

An important, but not essential, accessory for trolling is the outrigger or tangon, a long bamboo, fiber glass, or aluminum pole which is swung outboard to an angle of about 45° from the vertical when in use. The line, after the bait has been let out to the desired distance, is set in a clip which is hauled to the end of the outrigger. This gives an attractive action to the baits in an area outside the direct wake, as well as keeping them separated. It also serves to give the fish a "drop back" when the initial strike pulls the line out of the clip, perhaps making the fish believe that he has stunned his prey and certainly giving him time to take it back into his mouth so that the chances of hooking him are better. When fishing "directly" (without an outrigger) the angler must be constantly alert and ready to give the necessary "drop back" by releasing the drag on his reel at the critical moment.

Handline fishing is commonly practiced by commercial fishermen in the Caribbean. Called "cordeles" by the Venezuelans, the handlines basically consist of one or more hooks fastened to a strong wire leader which is in turn attached to the handline made of hemp or other suitable material (Fiedler, Lobel, and Lucas, 1947). The fishermen drift in certain areas with their lines at various depths waiting for a fish to strike.

The Cuban criollo line (palangre criollo) is a modified version of the handline. It consists of three lines of different lengths, each attached to a float and connected to each other and to the boat or an identifying buoy by a horizontal line. The interval between the floats is about 12-15 m. The standard set consists of 10 of the 3-hook outfits placed about 90 or 180 m apart in a straight line (Farrington, 1971).

The most widely used and productive commercial method for the capture of white marlin is the Japanese longline. Known as "palangre" or "palangre japonais" to Cuban and Venezuelan fishermen, it consists of a horizontal mainline to which vertical branch lines, each consisting of a short length of line, a leader (often of two components), and a hook, are attached at regular intervals. The basic unit is a "basket," which consists of a specified length of mainline with a specified number of branch lines attached. Enough baskets are fastened together to form a set of the desired length. The fishing depth is determined mainly by the length of the dropper lines which connect the mainline, at each junction between "baskets," to buoys (Captiva, 1955; Yoshida, 1966; Gottschalk, 1972). In a modernized variation of the longline, designed to increase the speed of operation and reduce manpower requirements, a continuous mainline is stored on a power-driven reel or drum, and branch and float lines are attached as the mainline is set and removed as it is retrieved (Captiva, 1955; Anon., 1966). The physical characteristics of the longline gear vary according to the sizes and species of the intended catch. The fishing depth is also selected to take advantage of the observed hydrographic conditions and the known habits and preferences of the fish whose capture is desired.

Since the white marlin is very sensitive to water temperature, surface thermometers are useful to fishermen who troll on the surface, whereas bathythermographs are more helpful to longline and handline fishermen.

5.12 Boats

Various types of boats are used for white marlin fishing ranging from the large oceangoing longliners and some very expensive sport fishing craft down to outboard motorboats and small 4.5- to 6-m wooden sailboats and rowboats of the Caribbean area.

Power, too, ranges from a pair of oars or lateen sail, through outboard motors of all sizes, to the large expensive engines needed to power high-speed sport fishermen or 60-m longliners.

The sport fisherman needs only a roomy cockpit and enough power and range to take him where he wants to go and troll at the required speeds (Jaen, 1964). Everything else is surplus equipment depending on how comfortable he wants to be and how fast he wants to travel. Appropriate models are available from the 5.5-m open outboard to the luxurious, expensive, twin engine sport fishermen.

Commercial vessels range from small rowboats or sailboats to converted trawlers and snapper schooners rerigged for longlining (Bullis, 1955) to the specialized Japanese fishing vessels described by Yoshida (1966).

5.2 Fishing Areas

5.21 General geographic distribution

See 2 and 5.22.

5.22 Geographic ranges

White marlin fisheries range from the coastal waters out to mid-ocean areas. The longline fishery, however, is the only one operating much beyond the continental shelves. Most of the sport fishermen and the smaller commercial boats fish from 1 km off the coast to the edge of the continental shelf.

In the area from Cape Hatteras, N.C., to Cape Cod, Mass., white marlin are sought by sport fishermen traveling as far as 130 km offshore to the canyons along the edge of the continental shelf. Fish have been captured as far north as Nova Scotia but these are probably strays that wandered further to the north than usual in especially warm summers (Morrow, 1965). The major center of abundance in this region seems to be from off Cape Hatteras to off Atlantic City (Mather et al., 1972). The Jack Spot, a shoal 36 km southeast by south of Ocean City has become internationally known (Farrington, 1937; Migdalski, 1958).

Havana, Cuba, and the northwestern Bahamas are other areas of intense fishing. The Cuban commercial fishermen travel only from 1 to 6 km offshore before setting their lines in the Straits of Florida (Farrington, 1971) and sport fishermen at Walkers Cay, Cat Cay, and Bimini in the Bahamas, and at Miami can be putting out lines within minutes of leaving the dock.

The sport and small-boat commercial fisheries off Venezuela are centered about 24 km offshore. Farrington (1949a) noted the abundance of white marlin off Caracas but realized the need for improved equipment and crews with greater maturity and experience before it would be utilized. By 1958, Migdalski predicted that the area north of Venezuela would be another Ocean City and Jaen (1964) calls it the paradise for white marlin anglers.

A newly developing area of interest which shows a promise of abundance is in the northern Gulf of Mexico (Mather et al., 1972). White marlin also occur along the eastern coast of South America as far south as Rio de Janeiro, off the Azores, Madeira, Portugal, southern Spain, and South Africa.

5.23 Depth ranges

Parin (1968) reports that during feeding excursions marlin may pass even into the upper levels of the main thermocline 200-250 m in depth. Their usual range, however, varies between the surface and 20-30 m. Studies of the results of the Japanese longline fishery also indicate that almost all billfish catches are made while the line is moving near the surface (Watanabe, 1961).

5.24 Conditions of the grounds

De Sylva and Davis (1963) give the most detailed description of conditions on white marlin grounds.
See 2 and 4.6.

5.3 Fishing Seasons

5.31 General pattern of seasons

See 2 and 3.5.
The white marlin ranges farther into the temperate zones during the warm seasons and congregates seasonally in certain coastal areas. Along the eastern United States, white marlin are abundant during the warm season from Cape Hatteras north to Cape Cod as well as in the Gulf of Mexico. During the colder seasons the marlin congregate in the more southern waters of the Bahamas—peak in spring—and Venezuela—peak August-October—where they can be found at all seasons of the year (Mather et al., 1972).

The offshore fishery reflects the same general pattern with longline catches being greater in north and south temperate waters during their respective warm seasons and higher in tropical areas in the cold ones (Ueyanagi et al., 1970; Wise and Davis, 1973). The middle of fall marks the beginning of the major southward movement from North Atlantic fisheries after the marlin have moved offshore from the coast (Mather et al., 1972).

5.32 Dates of beginning peak and end of season

See 2 and 3.5.
In the middle Atlantic coast sport fishery, white marlin arrive at Cape Hatteras in June and move north all the way to Cape Cod with fishing lasting until October in some areas. The peak usually progresses northward starting off Oregon Inlet, N.C., in July and moving up to Ocean City in late July and early August and on up to Montauk, Long Island, in late August before the fish move offshore in September (Mather et al., 1972).

Although some white marlin are available to sport fishermen off the Bahamas throughout the year, they appear off the northwestern Bahamas, northern Cuba, and southeastern Florida in greater numbers in January and stay until June, with the best fishing from mid-April to mid-June (Migdalski, 1958).

The sport fishing season for white marlin in the northern Gulf of Mexico extends from early June into October with peaks off the Mississippi Delta in July and in the northeastern Gulf in August (Nakamura and Rivas, 1972).

The Venezuelan sport fishery also produces some

white marlin on a year around basis, but the really intensive fishing occurs from August through October. The fish start moving into the western coast in July. Schools may be seen off Puerto La Cruz (Distrito Federal), moving east progressively until they reach La Guaira (the port of Caracas) in September (Jaen, 1964).

The seasonal trends in the oceanic longline catches of white marlin differ considerably from those of the inshore sport fisheries. The former are illustrated in Figure 5, on which the following discussion is based. In the North Atlantic, most of the successful fishing in winter occurs off the north coast of South America. In spring, the most productive areas are around the West Indies and the Bahamas, and in the western Caribbean and the Gulf of Mexico. The latter two areas are the only productive ones in the summer. In early fall, catch rates are high in oceanic waters off the middle Atlantic coast of the United States out to long. 55°W, and also in the Gulf of Mexico. Otherwise there is little longline fishing success in the fall until catch rates improve in the southeastern Caribbean in December.

In the South Atlantic, the most important longline catches occur from September through February off Brazil. The location and extent of this fishery varies from month to month, gradually shifting southward. There are also scattered areas of high catch rates in various months, expecially spring, in mid-ocean, and another concentration occurs in June-July between lat. 5° and 15°S, long. 5°E, and the African coast.

5.33 Variations in date or duration of seasons.

Nothing appears in the literature dealing with variations in the seasons of offshore longline fisheries.

Several factors have been noted which contribute to variations in the seasons of some of the sport fisheries. If there were not an accumulation of small forage fishes on which the white marlin could thrive or if the water temperature were not satisfactory, Farrington (1949a) noted white marlin may not occur in the Ocean City area in quantities. Earle (1940) also showed that records from the Ocean City fishery show a direct relationship between catches and water temperatures. Nakamura and Rivas (1972) reported that the bluer the water in the South Pass, La., and Northwest, Fla., areas the greater the abundance of white marlin. Current also plays an important role off South Pass. The Loop Current, which comes through the Yucatan Channel up toward South Pass and loops eastward to the De Soto Canyon and down through the Straits of Florida, holds the fish together and brings them right up to South Pass when it is strong, but when it is weak and failing, the fish scatter all over the Gulf of Mexico (H. B. Howcott, pers. commun.) The dates and durations of seasons are influenced by the times when these factors become favorable or unfavorable.

5.4 Fishing Operations and Results

5.41 Effort and intensity

The effort of longline fisheries is easily measured by the number of hooks set, which is usually recorded in thousands. The catch per unit of effort is usually recorded in terms of fish per 100 hooks or per 1,000 hooks. In handline or troll fisheries, effort is usually recorded by boat-days, although greater refinement may be achieved by considering boat- or line-hours. The catch per unit of effort is recorded in the terms in which the data are available.

The effort of Japanese longline vessels in the Atlantic, 1956-70, in numbers of hooks fished by years and areas (Fig. 13) is shown in Table 7. These correspond with the catch rates for white marlin shown in Table 6. Logbook data for annual fishing effort for the years 1956-70 by months and 5° (lat. and long.) quadrangles have been published by Shiohama et al (1965) and the Research Division of the Fisheries Agency of Japan (1965, 1966, 1967a, 1967b, 1968, 1969, 1970, 1971, 1972). Factors to adjust these data to estimates for the whole fleet are supplied by Wise and Davis (1973).

Since comparable data are not available for other longline fisheries, it is difficult to estimate total fishing effort. The Japanese effort reached a peak of nearly 100 million hooks in 1965 and has ranged between about 30 million and 42 million from 1967 through 1970. The numbers of Canadian, Japanese, Korean, and Taiwanese vessels which fished in the Atlantic in various years from 1960 through 1971 may give some idea of the relative effort of these fisheries (Miyake and Tibbo, 1972). While the Japanese effort from 1966 through 1970 was well below the 1965 peak, the increased participation of Korean and Taiwanese vessels kept the total effort high in most of those years and the number of Japanese vessels rose sharply in 1971. The Canadian fishery, which was for swordfish, *Xiphias gladius*, and a similar United States fishery, for which we have no effort data, were virtually terminated in 1970 because of the discovery of heavy metals in swordfish. Likewise, we have no effort data for Scandinavian longline fisheries, which were primarily directed toward the porbeagle shark, *Lamna nasus*, but also caught white marlin like the Canadian and United States fisheries (neither country of which marketed this species).

There are several Latin American commercial fisheries directed toward tunas and billfishes—all of which are marketed in the respective countries. In addition to its local small-boat fishery, Cuba has 4 longliners of about 400 gross tons each and 19 of about 700 gross tons each (Ferrer Guzmán, Carrillo Cárdenas, and Jimenez Guerras, 1972). These vessels fish in the tropical Atlantic, the Gulf of Mexico, and the Caribbean Sea. The Venezuelan longline fishery based at Cumaná originated in 1959 and leveled off at about 40 vessels of from 20 to 300 gross tons which fish

Table 7.—Numbers of hooks (in thousands) fished by the Japanese longline fishery in the Atlantic, by years, 1956-70, and areas, (see Fig. 13). Data furnished by J. P. Wise (pers. commun.).

Year	Fishing effort										
	GM(0)	NOW(1)	NOE(2)	CAR(3)	GUI(4)	CU(5)	GG(6)	BAH(7)	BEN(8)	RIO(9)	Total
1956	0	0	0	0	129	0	0	2	0	0	131
1957	0	0	0	5	867	1,133	1,328	42	0	0	3,376
1958	0	0	0	290	3,534	2,019	1,806	353	0	0	8,001
1959	0	4	6	258	4,300	5,419	3,009	2,294	4	17	15,312
1960	0	2	127	330	4,704	5,649	5,609	3,918	379	7	20,727
1961	0	55	275	92	1,616	5,416	10,942	4,833	3,346	84	26,660
1962	0	4,177	161	1,324	12,260	8,076	9,884	12,028	6,012	997	54,921
1963	433	9,478	233	2,560	10,100	9,163	9,182	6,003	5,049	2,803	55,004
1964	2,556	17,098	1,830	2,628	17,172	12,956	5,191	11,387	8,912	5,269	84,998
1965	519	14,231	3,535	1,909	17,192	14,127	18,273	5,761	16,775	5,258	97,580
1966	263	5,997	1,244	4,538	4,168	7,585	6,905	7,446	12,774	2,871	53,791
1967	345	4,495	774	175	3,824	5,930	6,230	1,814	5,638	1,928	31,154
1968	652	3,459	645	806	3,523	3,769	4,252	1,169	8,515	3,411	30,200
1969	158	3,382	268	1,061	3,994	3,784	4,262	451	7,254	5,063	29,676
1970	1,460	8,382	1,796	977	3,413	1,809	3,032	592	12,251	7,842	41,554
Total	6,388	70,761	10,894	16,952	90,796	86,835	89,906	58,092	86,909	35,551	553,085

mainly in the eastern Caribbean and adjacent Atlantic waters (Mihara and Griffiths, 1971). Five Brazilian longliners set 598,000 hooks in 554 fishing days in 1971 (Paiva, 1972). Miyake and Tibbo (1972) show only small (less than 50 ton) annual catches of Atlantic billfishes for Mexico (1964-70) and the Union of Soviet Socialist Republics (1967-71), but we found no further information on these fisheries. Moroccan, Portuguese, and Spanish trap and hook and line fisheries also take some white marlin (Furnestin et al., 1958; Rodríguez-Roda and Howard, 1962; Robins, 1974).

The average geographical distribution of the Japanese longline fishery in terms of intensity is shown by quarters of the year by Wise and Davis (1973, Fig. 3). Most of the effort is in tropical waters. Extensions of intensive effort to latitudes higher than 20° occur in the central North Atlantic during each quarter and in the western North Atlantic, including the Gulf of Mexico, in the second and third quarters. In the South Atlantic, such extensions occur mainly on the western side in the first quarter and on the eastern side in the second and third quarters. In the fourth quarter, the southward extension is nearly oceanwide.

Seasonal changes in effort are probably caused mainly by the seasonal distributional cycles of the species being fished, which are in turn affected by various factors (see 2.2, 2.3).

Year-to-year changes in effort are probably caused, for the most part, by the interaction of economic and biological factors. The basic determinants are, for capitalistic countries at least, the market value of the fish and the costs of catching them. Naturally, costs depend on wage scales and the costs of boats, equipment, and bait, as well as the availability of the fish. Since the white marlin is usually an incidental catch, however, the commercial fishing effort to which it is subjected is usually determined by the economics of the fisheries for more important species, such as the yellowfin tuna, the albacore, *Thunnus alalunga*, and the bigeye tuna, *T. obesus*.

The effort of sport fisheries is much more difficult to determine. Hundreds of charter and thousands of private sport fishing boats fish for white marlin from Cape Hatteras to Cape Cod, off southeastern Florida, in the Gulf of Mexico, off the Bahamas and the West Indies, and off Venezuela. The number of boats is difficult to estimate, as many move from place to place seasonally. The actual effort for white marlin is even more difficult to estimate, since other species are usually being fished for concurrently, and boats often divide their effort, over the season or the year, among various types of fishing.

Nakamura and Rivas (1972) listed the effort expended by members of the New Orleans Big Game Fishing Club off South Pass, La., 1967-71, and by anglers from the Florida ports of Destin, Panama City, and Pensacola in 1971. The effort varied between 2,339 and 5,801 boat-hours per season off South Pass and totalled 7,890 boat-hours in one season off the three Florida ports.

When the white marlin sport fishery at Ocean City began in 1936, there were 12 charter boats and by 1939, there were 39. After the lull during World War II, there were about 40 boats during the period from 1946 through 1953 (June and Reintjes, 1957). Since then the number increased to the present level of about 70.

The number of boats in the Venezuelan international fishing tournaments (in most of which sailfish and blue marlin are taken, as well as white marlin) increased from the low to middle 20's in the earlier years to 43 in 1970 (Anon., 1971).

The number of boats in the Atlantic City Marlin

Tournament has been as high as 200 in 1964 and 1965, but has declined to 120 to 130 in recent years (Atlantic City Public Relations, pers. commun.).

5.42 Selectivity

There appears to be little difference between the various hook and line gears as to the sizes of white marlin taken (see 4.13). Full selectivity in regard to the species of fish taken by the various gears is also difficult. With deep fishing methods (longline and handlines), selection may be attempted by the areas, seasons, depths, and environmental conditions in which fishing is carried out. In surface fishing, the areas, seasons, and environmental conditions are also instrumental in determining the species caught. This may also be influenced, however, by fishing tactics, such as type and size of bait or line and hook, position of bait or lure relative to boat, and trolling speed.

5.43 Catches

The total annual yield of white marlin as recorded by the FAO Yearbook of Fisheries Statistics (FAO, 1971) declined from about 5,000 tons in 1965 to about 1,000 tons in 1967-70. These totals, however, include figures for Japan and China (Taiwan) only (Table 8); the total catches must actually be considerably greater.

The Japanese white marlin catch attained highs of 163,415 fish and 4,600 tons in 1965, and has varied between about 27,000 and about 43,000 fish weighing from 700 to 1,000 tons in the years 1967-70 (Table 8; J. P. Wise, pers. commun.). The Taiwanese fishery took from 100 to 500 tons of white marlin annually in 1966-70 (Table 8). No data are available for white marlin catches of Korea, Cuba, Venezuela, and Brazil, but figures for the yearly catches of "others" (fishes other than albacore, yellowfin, bigeye, and bluefin tunas) by Korea, and of "billfishes" (marlins, sailfish, and spearfishes) by Cuba, Venezuela, and Brazil are provided by Miyake and Tibbo (1972). These authors' data indicate that white marlin comprised an average of 1.9% (by weight) of the total Japanese longline catches in 1967-71. Assuming that the tonnage of white marlin formed a similar percentage of the Korean catches, the estimated yearly totals increased from about 210 tons in 1967 to 705 tons in 1971. The Cuban catches of "billfishes" in 1961-71 ranged from 300 to 1,700 tons; those of Venezuela in 1968-71, from 300 to 500 tons; and those of Brazil in 1962-71, from 100 to 200 tons. In the Japanese Atlantic longline fishery, 1964-70, catches of white marlin constituted from 29 to 36%, by weight, of the total catches of marlins and sailfish, with an average of 33% (FAO, 1971). Catches of the Canadian and United States fisheries are not known, since the white marlin caught were discarded as no market exists in those nations. The considerable effort expanded by these fisheries in waters frequented by white marlin, however, must have resulted in numerous captures. The same is true of the Scandinavian longline fisheries which operated in the western North Atlantic in the early 1960's. The white marlin catches of Moroccan, Spanish, and Portuguese fishermen are likewide unknown. The total yearly commercial catches of white marlin in the years 1962-70 probably ranged between 2,000 and 6,000 tons (see 4.22).

Total catches for the numerous sport fisheries could only be estimated, but certain results from some of these areas are available to give indications. The Atlantic City Marlin Tournament catches have ranged from 7 fish in the first 3-day tournament in 1955 to 223 in 1963. Table 9 shows the catches, number of days fished, and number of boats fishing (Atlantic City Public Relations, pers. commun.). The numbers of white marlin caught in the Gulf of Mexico by the

Table 8.—Nominal catches of white marlin by fishing areas and by countries, as reported to the FAO (FAO, 1971).

Atlantic white marlin	**4.0**	**5.0**	**3.0**	**1.0**	**1.0**	**1.0**	**1.0**
Tetrapturus albidus (= *Makaira albida*)							
Atlantic, Northwest	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	--	(0.0)
Japan (. . . D)	0.0	0.0	0.0	0.0	0.0	--	0.0
Atlantic, Northeast	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	--	(0.0)
Japan (. . . D)	0.0	0.0	0.0	0.0	0.0	--	0.0
Atlantic, Western Central	(1.3)	(1.6)	(1.5)	(0.2)	(0.1)	(0.4)	(0.4)
China (Taiwan) (. . . D)	--	--	--	0.1	0.0	0.1	0.1
Japan (. . . D)	1.3	1.6	1.5	0.1	0.1	0.3	0.3
Venezuela (Aguja blanca)	---	---	---	---	---	---	---
Atlantic, Eastern Central	(0.3)	(0.6)	(0.3)	(0.1)	(0.3)	(0.2)	(0.1)
China (Taiwan) (. . . D)	--	--	0.1	0.0	0.0	0.1	0.0
Japan (. . . D)	0.3	0.6	0.2	0.1	0.2	0.1	0.1
Atlantic, Southwest	(1.6)	(2.1)	(1.1)	(0.4)	(0.6)	(0.5)	(0.3)
China (Taiwan) (. . . D)	--	--	--	--	--	0.2	0.1
Japan (. . . D)	1.6	2.1	1.1	0.4	0.6	0.3	0.2
Atlantic, Southeast	(0.3)	(0.3)	(0.2)	(0.2)	(0.3)	(0.2)	(0.3)
China (Taiwan) (. . . D)	--	--	--	0.1	0.2	0.1	0.2
Japan (. . . D)	0.3	0.3	0.2	0.1	0.1	0.1	0.1

Table 9.—Atlantic City, New Jersey, Marlin Tournament, results 1955-70, from the Atlantic City Public Relations Department.

Year	White marlin caught	Number of boats	Number of days fished
1955	7		2
1956	13	97	3
1957	36	100	3
1958	117	110	3
1959	104	180	3
1960	20	228	3
1961	5	182	4
1962	144	135	4
1963	223	165	3
1964	118	200	4
1965	85	200	4
1966	17	140	2
1969		120	3
1970	70	130	4
1971			4
1972		110	4

New Orleans Big Game Fishing Club from 1966 to 1970 were 151, 113, 95, 38, and 22 respectively (Nakamura, 1971), and in Venezuela in 1970, 190 white marlin were caught in 3 days of September from 45 sport fishing boats (Anon., 1970). The Ocean City catches for the first active season of marlin fishing in 1936 were 175 but by 1939 the figure had jumped to 1,343 (Earle, 1940). Table 10 shows the white marlin landings in Ocean City from 1936 to 1971 (June and Reintjes, 1957; Reintjes and Roithmayr, 1960; Ocean City Marlin Club, pers. commun.) In 1972 Ocean City Public Relations reports 837 marlin recorded by the 2nd of October; while boats based at Hatteras and Oregon Inlet, N.C., reported catching 1,212 white marlin in 1971 (Oregon Inlet Charter Boat Association, pers. commun.).

6 PROTECTION AND MANAGEMENT

6.1 Regulatory (Legislative) Measures

6.11 Limitation or reduction of total catch

At the present time no limitations have been put on the white marlin fishery by any legislative body. The need for such measures is being studied and may be considered in the future by the International Commission for the Conservation of Atlantic Tunas. This body has been given regulatory authority over both tunas and billfisheries to maintain maximum sustainable yield.

6.12 Protection of portions of population

Although no official protection measures are presently in force, conservation of this species is being carried on by sport fishermen in many areas. Ocean City, Md., is one major area where conservation has become the rule rather than the exception. In 1934 only 84 out of 1,343 fish caught were released back into the ocean even though they would serve no practical purpose, but up to July in the 1956 season 500 of approximately 800 fish caught were released (Migdalski, 1958). Continuing this practice, nearly 60% of the Ocean City catch is released yearly, many with tags from the Woods Hole Oceanographic Institution to aid in tracing the migrations of the white marlin (Brooks, 1968).

Oregon Inlet, N.C., and southern New Jersey fishermen, too, are deeply involved in this important conservation effort. Of the 1,212 white marlin caught by Hatteras and Oregon Inlet-based boats in 1971, 800 were reported released and many of these were tagged (Oregon Inlet Charter Boat Association, pers. commun.).

Other areas where tagging and releasing of fish are practiced include Long Island, Cape Cod, the Bahamas, Florida, the Gulf of Mexico, Virgin Islands, and off Venezuela (Mather et al., 1972). Table 11 shows the number of white marlin tagged by years in these various areas by cooperating sport fishermen and the numbers of tags returned.

6.2 Control or Alteration of Physical Features of the Environment

Nothing found in the literature.

6.3 Control or Alteration of Chemical Features of the Environment

Nothing found in the literature.

6.4 Control or Alteration of the Biological Features of the Environment

Nothing found in the literature.

6.5 Artificial Stocking

Nothing found in the literature.

7 FISH POND CULTURE

Not applicable.

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Table 10.—Ocean City marlin history 1936 through 1971, recorded by the Ocean City Marlin Club.

Year	Total caught	Total released	Largest caught	Date first caught	Date last caught
1936	175	NR	112 lb.	NR	NR
1937	200	NR	130 lb.	NR	NR
1938	781	NR	118 lb.	23 June	5 Sept.
1939	1,259		113 lb.	16 June	26 Aug.
1940	134	19	114 lb.	20 July	23 Sept.
1941	107	3	111 lb.	28 June	15 Sept.
1942		No records kept during war years			
1943		" " " " " "			
1944		" " " " " "			
1945	227	2	92 lb.	13 July	14 Sept.
1946	374	50	96 lb.	6 July	1 Sept.
1947	509	60	110 lb.	27 June	15 Sept.
1948	260	18	100 lb.	25 June	20 Sept.
1949	108	1	90 lb.	22 June	18 Sept.
1950	317	11	115 lb.	20 June	29 Sept.
1951	283	33	103 lb.	25 June	1 Oct.
1952	349	88	123 lb.	29 June	23 Sept.
1953	824	282	114 lb.	28 June	1 Oct.
1954	1,022	525	129 lb.	24 June	8 Sept.
1955	520	279	94 lb.	23 June	24 Sept.
1956	1,616	947	130½ lb.	22 June	19 Sept.
1957	1,062	622	106 lb.	19 June	21 Sept.
1958	616	322	121 lb.	21 June	22 Sept.
1959	1,082	569	100 lb.	24 June	13 Sept.
1960	503	228	115 lb.	20 June	16 Sept.
1961	545	317	95 lb.	23 June	15 Sept.
1962	926	545	115 lb.	15 June	13 Sept.
1963	1,267	688	109 lb.	16 June	18 Sept.
1964	721	370	82 lb.	20 June	18 Sept.
1965	654	325	117 lb.	22 June	24 Sept.
1966	544	256	80½ lb.	1 July	18 Sept.
1967	1,146	721	106 lb.	4 July	10 Sept.
1968	1,735	925	105 lb.	26 June	29 Sept.
1969	2,507	1,696	94 lb.	17 June	1 Oct.
1970	2,098	1,520	91 lb.	12 June	14 Oct.
1971	2,206	1,635	108½ lb.	19 June	10 Oct.

Important additional support has been received from the Sport Fishing Institute as well as from many sport fishing organizations and individual sportsmen.

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Table 11.—Releases (after slash) and returns (before slash) for white marlin, *Tetrapturus albidus*, grouped by major tagging localities. Nearly all were caught on rod and reel (trolling) and tagged by sport fishermen cooperating with Woods Hole Oceanographic Institution.

Year	Hatteras to Chesapeake	Chesapeake to Barnegat	Barnegat to Cape Cod	Oceanic North Atlantic	S.E. Florida and W. Bahamas	West Indies and vicinity	Gulf of Mexico	Venezuela and vicinity	Cozumel and Yucatan	Totals
1954			0/4							0/4
1955		1/116				0/8	0/21			1/145
1956		1/402				0/3	0/8			1/413
1957	0/3	0/140	0/1	0/1						0/145
1958	0/1	0/39	0/1							0/41
1959		0/190	0/10					0/2		0/202
1960		0/96	0/2		0/4	0/1	0/4	0/4		0/111
1961	0/2	2/187	0/10		0/13	0/9	0/11	0/30		2/262
1962	0/30	4/294	0/18		0/41		0/4			4/387
1963	0/75	4/533	0/4	0/3	0/35		0/10			4/660
1964	4/182	8/258	0/1	0/5	1/67		0/13			13/526
1965	0/15	6/258	0/5		0/67	0/5	0/10	2/25		8/385
1966	1/36	9/172	1/64	0/6	1/54	0/4	0/23	4/149		16/508
1967	0/37	6/234	0/6		0/88	0/7	1/46	0/103		7/521
1968	2/100	15/569	1/32		1/95	0/16	0/56	0/16		19/884
1969	8/360	12/829	0/27		2/86	0/18	2/35	2/46		26/1,401
1970	12/320	8/463	1/55		2/49	0/15	0/24	0/17	0/4	23/947
1971	2/247	11/559	0/17		1/57	0/20	0/18	0/95	0/4	14/1,017
1972	0/167	0/164	0/14		0/36	0/10	0/62	0/21	0/1	0/475
Unknown	2/2	4/4					1/1			7/7
Totals	31/1,577	91/5,507	3/271	0/15	8/692	0/116	4/346	8/508	0/9	145/9,041

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Synopsis of the Biology of the Sailfish, *Istiophorus platypterus* (Shaw and Nodder, 1791)[1]

G. L. BEARDSLEY, JR.,[2] N. R. MERRETT,[3] and W. J. RICHARDS[2]

1 IDENTITY

1.1 Nomenclature

1.11 Valid name

Istiophorus platypterus (Shaw and Nodder, 1791) (Fig. 1).

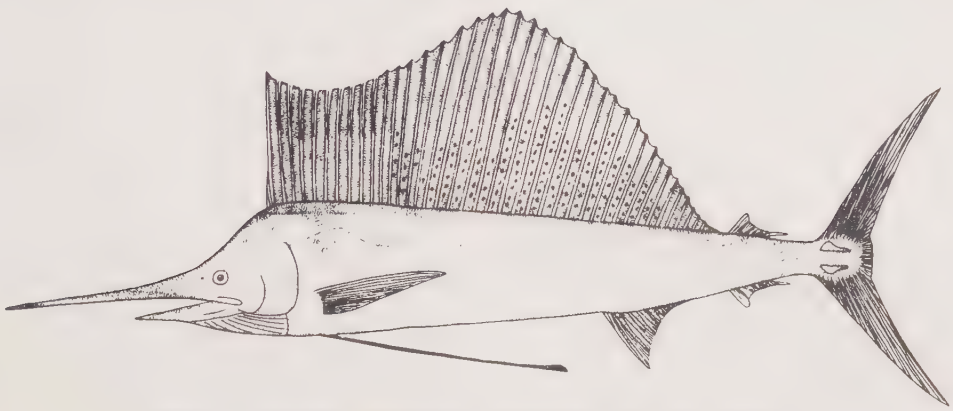

Figure 1.—Sailfish, *Istiophorus platypterus* (Shaw and Nodder, 1791).

Originally described as *Xiphias platypterus* Shaw and Nodder, 1791. Type locality, Indian Ocean. Holotype, British Museum of Natural History (BMNH) Catalog No. 1964.7.2.1 (G. Shaw and F. P. Nodder. 1791. *Xiphias platypterus*. The broad-finned swordfish. Natural Misc. No. 28. pl. 88).

1.12 Objective synonymy (modified after Morrow and Harbo, 1969).

Xiphias platypterus Shaw and Nodder, 1791 (see above).

Scomber gladius Block, 1793. Type locality, East and West Indies. Type specimen, none.

Xiphias velifer Block and Schneider, 1801. Type locality, India. Replacement name for *S. gladius* Block, 1793.

Istiophorus gladifer Lacépède, 1802. Type locality, Indian Ocean. Type specimen, none (based on Broussonette's "Le Voilier").

Histiophorus indicus Cuvier, *in* Cuvier and Valenciennes, 1831. Type locality, Indian Ocean. Holotype, BMNH Catalog No. 1964.7.2.1.

Histiophorus americanus Cuvier, *in* Cuvier and Valenciennes, 1831. Type locality, Atlantic Ocean off Brazil. Type specimen, none (based on Marcgrave's description and figure).

Histiophorus pulchellus Cuvier, *in* Cuvier and Valenciennes, 1831. Type locality, South Atlantic. Holotype, a juvenile, current location unknown.

Histiophorus gracilirostris Cuvier, *in* Cuvier and Valenciennes, 1831. Type locality, Mauritius (?). Holotype, Masée National d'Histoire Natural, Paris (NMHN) Catalog No. A9462.

Histiophorus ancipitirostris Cuvier, *in* Cuvier and Valenciennes, 1831. Type locality, Red Sea. Holotype, NMHN A9463.

Makaira velifera Cuvier, 1832. Type locality, Haiti. Holotype, NMHN Catalog No. B1648 (?).

Histiophorus orientalis Temminck and Schlegel, 1844. Type locality, Japan. Type specimen, none extant, based on a fresh specimen.

Histiophorus immaculatus Rüppel, 1835. Type locality, Red Sea near Djedda. Holotype, an 18-inch juvenile, whereabouts unknown.

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Histiophorus granulifer Castelnau, 1861. Type locality, Cape of Good Hope. Holotype, a mutilated skeleton, said to be in the Capetown Museum.

Istiophorus greyi Jordon and Evermann, 1926. Type locality, Cape San Lucas, lower California. Type specimen, California Academy of Sciences (CAS) Catalog No. 605, a photograph.

Istiophorus wrighti Jordan and Evermann, 1926. Type locality, off Miami, Fla. Type specimen, CAS Catalog No. 603, a photograph.

Istiophorus maguirei Jordan and Evermann, 1926. Type locality, off Long Key, Fla. Type specimen, CAS Catalog No. 604, a photograph.

Istiophorus volador Jordan and Evermann, 1926. Type locality, off Long Key, Fla. Type specimen, CAS Catalog No. 606, a photograph.

Istiophorus eriquius Jordan and Evermann, 1926.[4] Type locality, Hawaii. Holotype, Bernice P. Bishop Museum Catalog No. 3424.

Istiophorus brookei Fowler, 1933. Type locality, Tahiti. Holotype, Academy of Natural Sciences, Philadelphia Catalog No. 55923.

For further lists see Nakamura, Iwai, and Matsubara (1968).

Several authors have recently considered the senior synonym of the Atlantic form of the sailfish to be *Istiophorus albicans* (Latreille, 1804). Whitley (1939) first called attention to a series of volumes entitled "Nouveau Dictionaire d'Histoire Naturelle" published in Paris from 1802 to 1804. The fish sections in these volumes were by L. A. G. Bosc and are clearly designated with the letter (B) at the end of each fish account. Bosc (1803) in volume 13 described the Atlantic sailfish based on Marcgrave's description and figure. Bosc applied the common name 'le makaira blanchâtre' to this species. Latreille (1804) in volume 24, following his description of the genus *Makaira*, clearly applied a scientific name to Makaira blanchâtre, in the following manner: "Makaira blanchâtre, *makaira albicans* Bosc." Latreille wrote nothing else, thus under the International Rules of Zoological Nomenclature this name must be considered a nomen nudum. Had Latreille referred to Bosc's description in the earlier volume the name would be available.

1.2 Taxonomy

1.21 Affinities

Suprageneric

Phylum Chordata
Subphylum Vertebrata
Superclass Gnathostomata
Class Osteichthyes
Subclass Actinopterygii
Order Perciformes
Suborder Xiphioidei
Family Istiophoridae

Gosline (1968) in his review of perciform suborders presented evidence that the relation of billfishes to scombrids and their allies may be one of convergence. He placed the family Istiophoridae along with the family Xiphiidae and provisionally, the Luvaridae, in a separate suborder Xiphiodei.

Generic

Monotypic genus, see specific diagnosis.

Istiophorus Lacépède, 1802. (ref.). Type species designated as *Istiophorus platypterus* (Shaw and Nodder, 1791). Holotype, BMNH 1964.7.2.1. Designated by Morrow and Harbo (1969).

Specific

Diagnosis, first dorsal fin very high, sail shaped, the middle rays decidedly the longest; the ventral fin rays very long and fin membrane well developed.

1.22 Taxonomic status

Two recent reviews have treated the sailfish genus *Istiophorus*. Morrow and Harbo (1969) and Nakamura et al. (1968). The latter recognized two species of sailfishes—*I. platypterus* (Pacific sailfish, Bashokajiki) from the Indo-Pacific and *I. albicans* (Atlantic sailfish, Nishibashokajiki) from the Atlantic. They based their separation on greater length of the pectoral fin and the caudal fin on Atlantic specimens less than 90 cm in length. Above 90 cm in length they are indistinguishable. Morrow and Harbo disputed this contention in a footnote on p. 39 of their paper saying that their data (though not presented) do not support such a distinction. In this synopsis we follow Morrow and Harbo, but emphasize that studies are needed to determine exactly the specific status of the genus *Istiophorus*.

1.23 Subspecies

Various authors have recognized subspecies. Based on Morrow and Harbo (1969) this does not seem to be justified.

1.24 Standard common names and vernacular names.

The names capitalized are official or in more common use. Compiled mostly from FAO (1950).

Arabia — FÁRAS
Brazil — AGULHÃO DE VELA, Agulhão bandeira, Agulhão, Bicudo, Guebuçú.

[4]Jordan and Evermann (1926) attribute *I. eriquius* to Jordan and Ball, but under present interpretation of the International Code of Zoological Nomenclature, Jordan and Evermann must be given the responsibility for the name.

British West Indies — SAILFISH, Billfish, Ocean gar, squadron, Mère, Balahoo, Mammon balahoo (Patois names).
Ceylon — SAILFISH, Thalapatha (Sinhalese dialect), Myl min (Tamil dialect).
China — TONG FANG CHIYII
Comores Is. — MBASSI KOURI
Cuba — AGUJA VOLADORA, Aguja de abanico, Abanico, Prieta, Voladora, Bicuda.
France — LE VOILIER
Ghana — AMERICAN SAILFISH, Onyankle (Ga), Adzietekwesi (Adanme), Fetiso (Fante).
India — SAILFISH, Yemungolah (Tamil dialect), Plain sailfish, Tadmása (Marathi dialect).
Japan — BASHOKAJIKI, Nishibashokajiki (Atlantic Ocean form).
Kenya — NSULI NSULI, Mbassi
Madagascar — NDWARO
Malaya — LAYER, Mersuji
Mexico — PEX VELA, Volador
Philippines — SAILFISH, Sailfin, Malasugi (Bikol), Kandayan, Kandelan (Marinao, Samal and Tao Sug), Dogso, Dugso, Malasugi, Liplipan (Visayan), Dumosok (Pangasinan).
Portugal — VELEIRO
Senegal — ESPADON, Oumbajhe
Sumatra — IKAN-JEGAN, Johoo malags
Taiwan — YU SAN YU, yu sanchiyu
Tanzania — NSULI NSULI, Mbassi
USSR — PARUSNIK-RYBA
Union of South Africa — SAILFISH
United States — SAILFISH, Atlantic sailfish, Pacific sailfish, Mexican volador, Pacific volador, Florida sailfish, Spikefish, Boohoo, Woohoo, Voilier, Volador, Au-lepe (Hawaiian).
Venezuela — AGUJA VELA
Vietnam — CÁ CO

1.3 Morphology (condensed from Nakamura et al., 1968; Morrow and Harbo, 1969).

1.31 External morphology

The dorsal fin is extremely high, sail shaped with the middle rays decidedly the longest. The ventral fin rays are very long, almost reaching the vent, and the fin membrane is well developed. On the sides of the body there are 10 rows of striped crest patterns consisting of many light blue dots. There is a clear crest on the outer edge of the head between the preocular area and the base of the first dorsal fin. The body is extremely flat; the cranium long and narrow. The neural spines and hemal spines of the central vertebrae form a triangular shape. There are 24 vertebrae (12 + 12 = 24). The lateral apophysis is not well developed.

There are two dorsal fins and two anal fins (counts are given in Table 1). The pectoral fin has 17-20 soft rays; the ventral fin has 1 spine and 2 soft rays. The caudal fin has 17 principal rays (9/8) and 20-22 secondary rays (10/10 or 11/11).

The body is elongated and laterally compressed. The snout is long and round in cross section. Many of the scales have a single point which is not sharp. The lateral line is easily distinguishable, curving above the pectoral fin and then continuing in a straight line toward the tail. The caudal fin is deeply forked and two scutes precede it on each side of the caudal peduncle. The pectoral fin is low on the body, relatively long and pointed. The second dorsal and second anal fins are small. Internally, the nasal rosette is radially shaped with about 48 nasal laminae. The abdominal cavity is extremely long, extending past the vent to the middle of the base of the second anal fin. The visceral organs are also elongate.

Other than the differences noted above between the

Table 1.—Number of dorsal and anal rays. (Modified from Morrow and Harbo, 1969; Merrett, 1971.)

	Number of dorsal fin rays																
	First dorsal fin														Second dorsal fin		
Region	37	38	39	40	41	42	43	44	45	46	47	48	49	$\bar{x}$	6	7	8
Atlantic	1	2	-	3	2	12	13	29	21	5	1	1	-	43.66	25	55	3
Peru									2	3	4			46.22	-	17	-
Pacific							1	-	5	4	7	5	2	46.63	7	17	-
Indian								1	3	2	7	5	-	46.67	1	18	-
Africa			3	-	3	15	16	9	10	3	4	-	3	43.59	7	34	2

	Number of anal fin rays													
	First anal fin										Second anal fin			
	8	9	10	11	12	13	14	15	16	$\bar{x}$	5	6	7	8
Atlantic	1	1	3	3	14	39	19	-	1	12.80	-	39	44	-
Peru				5	1	2	1			11.89		1	8	
Pacific					1	8	12	3		13.71		6	18	
Indian					2	10	3	1		13.19		4	13	
Africa	4	2	6	22	14	12	7			11.55	2	11	23	2

Atlantic and Pacific populations (see 1.22) there are some indications of possible differentiation of certain populations, but according to Morrow and Harbo (1969), "there is little consistency in the direction of these indications."

Morrow and Harbo show some differentiation with age, and Vick (1963) examined allometric and isometric growth of adult *I. platypterus* in some detail, but extreme differences are noted in the young and will be covered in 3.2.

1.32 Cytomorphology

Nothing found in the literature.

1.33 Protein specificity

Nothing found in the literature.

2 DISTRIBUTION

2.1 Total area

Sailfish are circumtropical, occurring in all warm waters of the world. In the Atlantic Ocean sailfish range from lat. 30°S to 30°N on the western side with only occasional stragglers beyond these limits. Voss (1953) stated that individuals taken as far north as the Gulf of Maine are apparently summer stragglers and their distribution is extended during long, hot summers with prevailing southerly winds. In the eastern Atlantic distribution is generally more restricted, from lat. 10°S to 20°N (Fig. 2). It may be inferred that the densest concentrations also occur in the western Atlantic close to land masses according to data from the Japanese longline fishery with the tacit realization that Japanese commercial vessels fail to

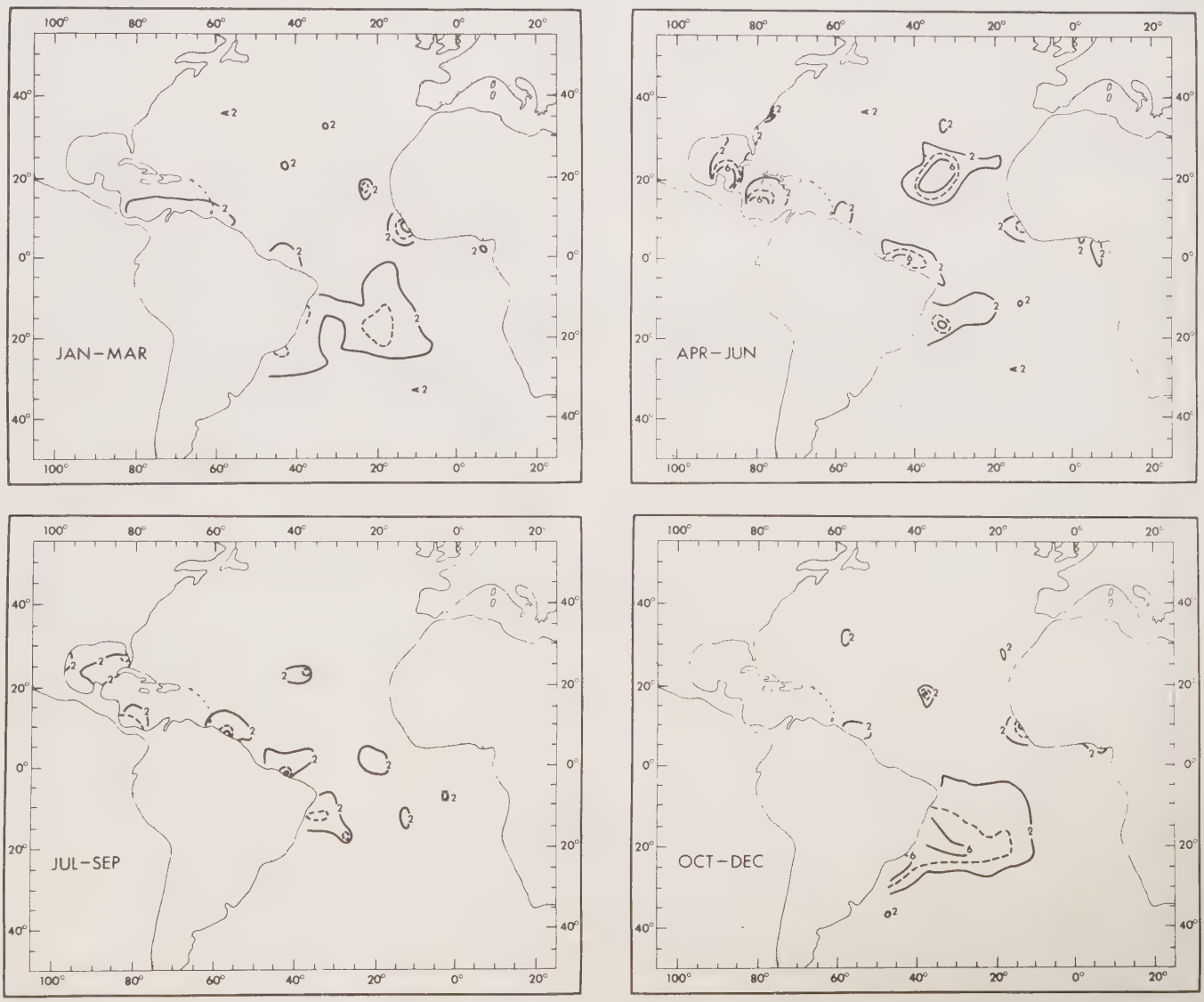


Figure 2.—Distribution of catches of sailfish and spearfish (per 1,000 hooks) in the four quarters of the year, 1956-68 (from Wise and Davis, 1973).

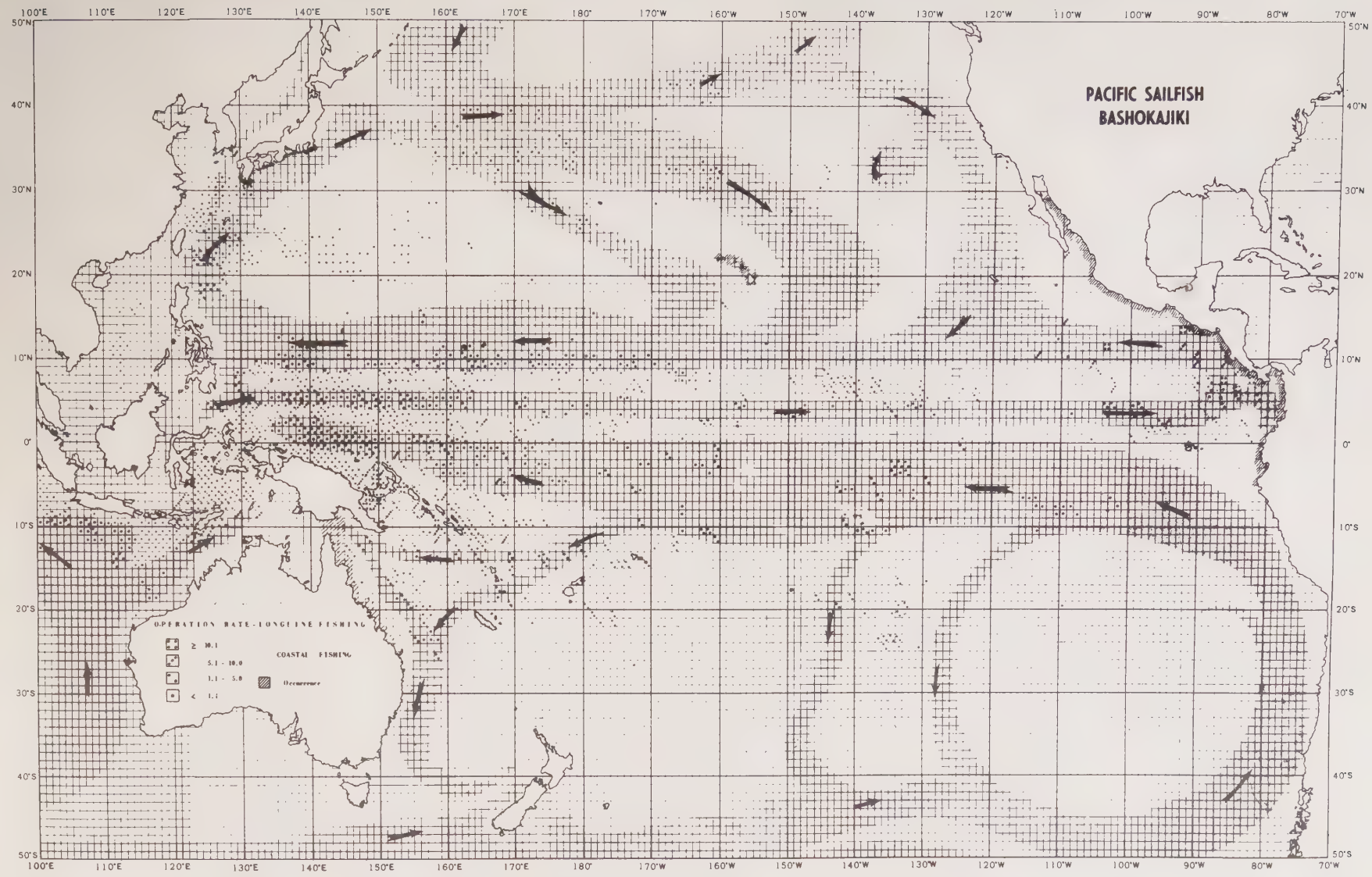


Figure 3.—Distribution of the sailfish, *Istiophorus gladius*, in the Pacific Ocean (from Howard and Ueyanagi, 1965).

differentiate between sailfish and spearfish. Ueyanagi et al. (1970) indicate, however, that concentrations of Atlantic sailfish are greatest on the western side. Large concentrations of sailfish in the Gulf of Mexico, along the southeast coast of Florida, and throughout the Carribbean are heavily fished by sports fishermen.

In the eastern Atlantic abundance is apparently low based on longline catch records. This may be misleading since there are no established sport fishing centers in the eastern Atlantic and longline operations are often not close enough to shore to detect sailfish concentrations. However, a localized area of high concentration of sailfish has been noted by Ovchinnikov (1970) off West Africa (the Freetown-Conakry region). He indicated that a similar accumulation of sailfish also occurred in the western Atlantic in the region of eastern and northeastern Brazil.

In the Pacific, sailfish distribution is also more extensive in the western half than in the eastern (Fig. 3). Longline catch data show sailfish catches as far south as 27°S and as far north as lat. 40°N. Koto, Furukawa, and Kodama (1959) reported heaviest concentrations near New Guinea, the Caroline Islands and Solomon Islands, and in the Banda Sea, Timor Sea, and East China Sea. Howard and Ueyanagi (1965) suggested that there is a close relationship between the distribution of sailfish in the western Pacific and the Kuroshio Current since both adults and juveniles are found in the coastal waters of Japan in the Kuroshio Current. In the eastern Pacific, longline catch records show a rather restricted distribution from lat. 5°S to 25°N (Kume and Joseph, 1969a). High catch rates near the coast of Mexico indicate areas of high abundance. Sailfish are caught by sport anglers near shore from the Gulf of California to northern Peru.

There is little information on sailfish distribution in the Indian Ocean. Williams (1964) indicated that sailfish are distributed throughout the East African coastal area from lat. 1°30′N to 10°30′S with localized concentrations. Japanese longliners catch small numbers of sailfish throughout most of the Indian Ocean to at least lat. 29°S in the western Indian Ocean.

Sailfish have been reported from the Mediterranean; however, most of these reports were based on larval or juvenile specimens and in at least one case (Ben-Tuvia, 1966) have been subsequently identified as the Mediterranean spearfish, *Tetrapturus belone*. It is doubtful if sailfish occur in the Mediterranean.

2.2 Differential Distribution

2.21 Spawn, larvae, and juveniles

Gehringer (1956) reported on sailfish larvae captured in the western Atlantic and Gulf of Mexico from March through October. He concluded that early development of Atlantic specimens takes place in warm Gulf Stream waters. In a later paper (Gehringer, 1970) he examined larvae from the eastern Atlantic captured in April.

Ueyanagi (1959) found that sailfish larvae are closely associated with the Kuroshio Current in the western Pacific. In the eastern Pacific sailfish larvae and juveniles have been captured from September through April (Howard and Ueyanagi, 1965).

Jones (1959) reported on 16 sailfish larvae captured in February from the Laccadive Sea.

See also 3.16.

2.22 Adults

Sailfish are year-round residents over most of their range, however pronounced seasonal variations in abundance and distribution are evident in most areas. Wise and Davis (1973) showed that sailfish are caught off Brazil by longliners all year long, but catches are larger and over a broader area from October through March than from April through September. Greatest abundance in the Caribbean Sea and Gulf of Mexico is from April through September; few are caught in the winter months. Voss (1953) stated that sailfish are found off the lower Florida coast throughout the year in considerable numbers, but during the summer months they are less concentrated than in winter. Cadenat (1961) has shown that sailfish in the eastern Atlantic, off the Ivory Coast, are present inshore in greatest abundance during the winter months, but practically disappear from the coastal waters during August to November.

Howard and Ueyanagi (1965) reported that in the eastern Pacific sailfish are present all year but seasonal changes in density are marked. Kume and Joseph (1969a) stated that sailfish appear to be abundant off central Mexico all year with apparent seasonal movements. In the Gulf of Panama sailfish are most abundant from April-May through November-December with a peak from June to September. Near Acapulco, sailfish appear to be most abundant in winter. From the Gulf of California northward the period of greatest abundance is from May to October.

Nakamura (1949) stated that sailfish are most abundant around June in the Kuroshio Current east of the Philippine Islands and Formosa, and Koto et al. (1959) indicated that sailfish are most abundant in the East China Sea from November through April with low densities from May through August.

There is little information on seasonal distributions in the Indian Ocean; however, at Malindi, Kenya, Williams (1970) reported that sport catches are restricted to the period October to March with peak catches in December and January. That sailfish show a peak in abundance during the northeast monsoon in

this and the broader area of the equatorial western Indian Ocean was confirmed by Merrett (1971).

2.3 Determinants of Distribution Changes

Voss (1953) stated that sailfish distributions along the east coast of Florida appear to be affected by wind and temperature. In the summer there is a "diffusion" of sailfish to the northward correlated with a northward extension of warm water. These same fish are driven southward to congregate in schools off the Florida coast with the beginning of cold weather and northerly winds.

Evidence presented by Ovchinnikov (1966) indicates that the frontal zone of the Canaries Current and the Equatorial Countercurrent is responsible for the aggregation of sailfish off the coast of West Africa. He stated that in spring sailfish move along the coast from south to north, and apparently move back again from north to south in the autumn, following the 28°C isotherm. Similarly, Cadenat (1961) indicated that the period of increased abundance off the Ivory Coast coincides with the periods of maximum surface temperature, around 28°C.

In the western Pacific the distribution of postlarvae and adult sailfish appears to be closely related to the Kuroshio Current (Nakamura, 1949; Ueyanagi, 1959). Nakamura also stated that the season of dense distribution in this area coincides with the spawning season. Koto et al. (1959) found that sailfish over 160 cm long migrate southward out of the East China Sea, presumably for spawning.

In the eastern Pacific, Kume and Joseph (1969a) found that seasonal north-south movements of sailfish off the coast of Mexico appear to coincide with the seasonal movements of the 28°C isotherm.

Williams (1964, 1970) concluded that the abundance and distribution of sailfish in the Indian Ocean off East Africa is positively correlated with the months of the northeast monsoons when the East African Coastal Current reaches its maximum temperature (29°-30°C) and minimum salinity (35.2-35.3‰). This is also the time of highest biological productivity in surface waters caused by a mixing due to the junction of the southward flowing Somali Current and the northward flowing East African Coastal Current. The inshore penetration of nutrient rich Somali Current water fluctuates seasonally. Williams (1970) summarized by stating that: "The known fluctuations in overall productivity and the seasonal abundance of shoals of pelagic fish in the north Kenyan area during the northeast monsoon might well be due to the fluctuations in the penetration of the SC tongue."

2.4 Hybridization

Nothing found in the literature.

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

Sailfish are heterosexual. There are no external characters known to distinguish males from females, although Jolley (1974) and Nakamura and Rivas (1972) indicated that large Atlantic sailfish were usually females.

3.12 Maturity

There is little information available on size at first maturity. Merrett (1971) examined gonads from 65 female sailfish from the equatorial western Indian Ocean but found only one immature specimen 130 cm long (measured from center of orbit to shortest caudal ray) and weighing 13.6 kg. According to de Sylva (1957) sailfish this size in the western Atlantic are approximately 18 mo old.

3.13 Mating

Mating in large pelagic fishes has often been assumed to be promiscuous with sexual products released indiscriminately and fertilization occurring by chance. Nakamura (1949) stated, however, that "Spawning (in sailfish) is carried on with a male and a female paired or two or three males chasing a single female, and this act can be seen often during the spawning season." Voss (1953) reported observing similar behavior in sailfish off the Florida coast. Sailfish were often sighted in groups of two or three swimming very slowly in shallow water. The ovaries of females captured in this area were all extremely large and very ripe. Voss also reported that another observer sighted two sailfish pressed tightly together and swimming slowly in shallow water. One was harpooned and was identified as a female containing ripe overies weighing about 3.2 kg.

3.14 Fertilization

Fertilization is probably external.

3.15 Gonads

According to Voss (1953) the number of eggs spawned by a female sailfish is large based on western Atlantic specimens. He determined that a 1.4-kg ovary contained 2.3 million eggs and obtained counts as high as 4.7 million eggs in later analyses. Voss also stated that gonads from female sailfish may be as long as 50.8 cm and weigh up to 3.6 kg. Jolley (1974) showed that ripe gonads of Atlantic sailfish weighed 8.1-12.5% (mean 9.9%) of total body weight. Fecundity estimates ranged from 0.75 to 1.56 million ova. Only the most advanced ova, 1.2- to 1.4-mm diameter, were counted. Ovchinnikov (1970) gave fecundity estimates of 1.6-11.5 million eggs from ovaries of 1.1-2.1 kg from Atlan-

tic sailfish. Merrett (1971) found as many as 19.5 million eggs in sailfish from East African waters and pointed out that fecundity increased sharply with fish size.

A definite relation between relative ovary weight (ovary weight $\times 10^3$/fish weight) in *I. platypterus* and the state of gonad development has been established (Merrett, 1971). Having demonstrated that egg diameter is a reliable means of determining the state of maturity of an overy, he compared the relative ovary weight with this criterion. It was found that while this character did not provide staging evidence throughout the oogenic cycle, it could provide for accurate diagnosis during the growth phase. Comparable application of relative testis weight was found to be less meaningful due to the lack of seasonal variation in testis weight of the sailfish examined. From a total of 111 male sailfish examined over a period of 3½ yr, none was found to be in a running ripe condition, although spermatozoa were present in all testes examined due to differential maturation of the lobules within the gonad. It was suggested that the viability of the male was maintained at all times, owing to the possession of a muscular seminal vesicle in which spermatozoa are stored. The vesicle is thought to be capable of active expulsion of milt and subsequent passive replenishment, at all times, by suction.

3.16 Spawning

In the Atlantic, Voss (1953) summarizing early accounts, stated that, "From the literature it can be seen that it has previously been considered, mostly through capture of gravid females, that the sailfish breed near or off the Florida coast and the consensus of opinion gives the time as the early summer." Voss also reported that larvae from 3.9 to 8.0 mm standard length were captured on the east side of the Gulf Stream from 29 May to 2 July. Voss believed that sailfish move into shallow inshore waters to breed. Gehringer (1956) stated that, ". . . spawning appears to extend from April to September from south of Cuba north to Carolina waters, and beyond the 100 fathom line." Gehringer also indicated that there was a northward shift of size occurrences of larvae as the season progressed, indicating a corresponding northward shift in general spawning season. De Sylva (1957) indicated an extended spawning season in the western Atlantic and that very young larvae were captured from late April until mid-August. He also cited a personal communication with Al Pflueger who stated that he had found ripe females off southern Florida as late as October. Jolley (1974) found ripening females prominent among Atlantic sailfish examined during May through September.

Spawning in the eastern Atlantic has been observed all year long (Ovchinnokov, 1970), with peak intensity during the summer months on the West African shelf in the Conakry-St. Louis region. Ovchinnikov (1970) stated that sailfish in the Conakry-Freetown region become mature in February, March, and April, and at the end of April the fish spawn intensively. Ueyanagi et al. (1970) reported taking sailfish larvae off Angola and Sierra Leone in the period November to April. Gehringer (1970) reported on 34 specimens from 13.8- to 238.0-mm standard length captured in the Gulf of Guinea in April, and Cadenat (1961) reported two larvae from the same area in February and April, 35 and 44 mm total length.

In the Gulf of Mexico, Baughman (1941a) stated that several ripe females were taken late in the season (probably late August) off the Texas coast, and females in all stages of maturity were captured in early August. Based on the occurrence of larvae and the surface current patterns in the Gulf of Mexico, Gehringer (1956) concluded that two separate spawning areas existed in the Gulf, one in the southeastern Gulf from April through August and the other in the western Gulf from June through August.

In the Pacific Ocean, sailfish apparently spawn throughout the year in warm tropical waters (Nakamura, 1932, 1940; Yabe, 1953; Ueyanagi, 1964). Based on the distribution and occurrence of larvae, Ueyanagi (1964) concluded that spawning took place in inshore waters near islands. The capture of ripe adults from the western Pacific has been reported by Nakamura (1949) in May, July, August, and December and by Ueyanagi (1964) in May, July, November, and December. Ueyanagi stated that although data were insufficient it appeared that the spawning season in the northwest Pacific and the South Pacific is in their respective summers.

Laurs and Nishimoto (1970) reported on five juvenile sailfish captured in September in the eastern Pacific off Central America. Surface temperature was 29.1°C, and high standing stocks of zooplankton were measured in the vicinity. Howard and Ueyanagi (1965) stated that W. L. Klawe reported to them the capture of juvenile sailfish in the equatorial waters of the eastern Pacific in the months of February, April, May, and December. Beebe (1941) reported the capture of two juveniles off the coast of Mexico, one in March and the other in November, and Howard and Ueyanagi reported on 11 juvenile sailfish taken in the Gulf of Panama in September. Based on these accounts, the spawning season in the eastern Pacific is lengthy, and probably some spawning occurs all year long.

Jones and Kumaran (1964) concluded from the distribution of larvae in the Indian Ocean that sailfish in the eastern Indian Ocean spawn west of Sumatra in September and October, and in the western Indian Ocean they spawn near Madagascar and the Seychelles Islands in December and January. Morrow (1964) examined sailfish at Taiwan and found running roe and milt in July. He stated that sailfish examined at Ceylon and the Maldive Islands in August and September, the Seychelles in October and November, and off the East African coast in January and March

1950 and November 1957-January 1958 were not in a breeding condition. He concluded that most istiophorids apparently spawn in the summer months, roughly May through September.

Williams (1963) stated that sailfish move into coastal waters of Kenya in December, January, and February for spawning based on the presence of mature and spent adults in the area. Merrett (1971), however, suggested that the abundance of sailfish in inshore waters off Kenya was not for spawning but was a postspawning, feeding migration and reported capturing two running-ripe sailfish on longline gear approximately 111 km from the coast, one in January and the other in April. Williams (1970) revised his earlier spawning hypothesis and concluded that a combination of the two hypotheses was most likely correct. Jones (1959) indicated an additional spawning locality in the Laccadive Sea.

3.17 Spawn

A redescription of the egg of *I. platypterus* is given by Nakamura (1949) who wrote: "The ripe ovarian eggs are about 0.85 mm. in diameter and they have a single oil globule. Around the oil globule there is a pale yellow indefinite nimbus. There are no structures on the vitelline membrane and the egg as a whole is almost colorless and clear." Merrett (1970) described oogenesis and spermatogenesis in this and other billfish species. He measured eggs shed from a captured sailfish and reported that the mean diameter was 1.304 mm. He also examined the morphology of the spermatozoa of this species and *Tetrapterus audax* and *Makaira indica*. Measurements showed the heads to be 1.3-1.9 μm in diameter; in length, the middle pieces measured 0.8-1.3 μm, and the tails up to 30 μm. The only difference observed between the species was that the heads of the spermatozoa in sailfish tended to be in the upper part of the diameter range, and the middle pieces were found generally to be shorter than in the other two species.

3.2 Preadult phase

3.21 Embryonic phase

(Defined as from fertilization to hatching, i.e., during incubation period.) Nothing found in the literature.

3.22 Larvae phase

See 3.23.

3.23 Adolescent phase

Since young of these fishes gradually transform from larvae to adults, both the larval phase and adolescent phase are discussed here in one unit.

Young billfishes (Istiophoridae) are all very similar in their development, and consequently identification of the young stages is difficult. The first description of a young sailfish was by Cuvier (*in* Cuvier and Valenciennes, 1831). This specimen was 108 mm long and is the type specimen of *Histiophorus pulchellus* (see 1.12). Rüppell (1835) reported on a 45.7-cm juvenile from the Red Sea which he described as *H. immaculatus*. Günther (1873-74) published figures of young billfish 9, 14, and 60 mm long, and these were republished in one of his later works (1880). Lütken (1880) also republished these figures as well as a 5.5-mm specimen of his own. It is difficult to say positively that the specimens of Günther and Lütken are in fact sailfish. Goode (1883) also republished these figures and included an English translation of Lütken (1880). LaMonte and Marcy (1941) described a 14-mm specimen, and Beebe (1941) described two 12-cm specimens. Beebe also reviewed briefly the early work mentioned above and republished all of the figures mentioned. However, the fine detail presented in the earlier figures was not reproduced by Beebe and for detailed study we recommend that the original work be consulted. Descriptions of occasional specimens thought to be sailfish have appeared prior to papers describing complete series. Such descriptions are by Nakamura (1932, 1940, 1942, 1949) and Deraniyagala (1952).

Two studies describing complete series of larval through juvenile stages of sailfish were published in 1953, one by Voss based on Atlantic specimens and the other by Yabe based on Pacific specimens. Following these two papers, several papers also described sailfish based on complete series or else give important data on young forms. These studies are by Gehringer (1956, 1970), Jones (1959), Sun (1960), Ueyanagi and Watanabe (1962, 1964), de Sylva (1963), Ueyanagi (1963b) Mito (1966, 1967), and Strasburg (1970). We have reproduced here the figures of larval sailfish from Gehringer 1956 and 1970 (Fig. 4) that best delineate changes which take place during development. The most striking features are the early development of prominent pterotic and preopercular spines, the beaklike snout, and the very dark pigmentation which is acquired in early stages. At lengths greater than 10 mm the large dorsal fin begins to develop and with the long bill make this a most striking juvenile.

When seen in life between 4 and 15 mm in length the dark area is dark metallic blue (brown when preserved); the belly silvery (white when preserved); the head area, particularly the opercles, are flecked with a brilliant gold (this is lost soon after preservation); and the dorsal fin is a deep velvety black. The juvenile is colored very similar to the adult.

Ueyanagi (1963a, 1964) gave methods for distinguishing sailfish young from the other billfish species in the Indo-Pacific. His methods (1964 paper) are as follows:

> It is not easy to identify the larvae of different istiophorid species, because of their close resemblance with each other and

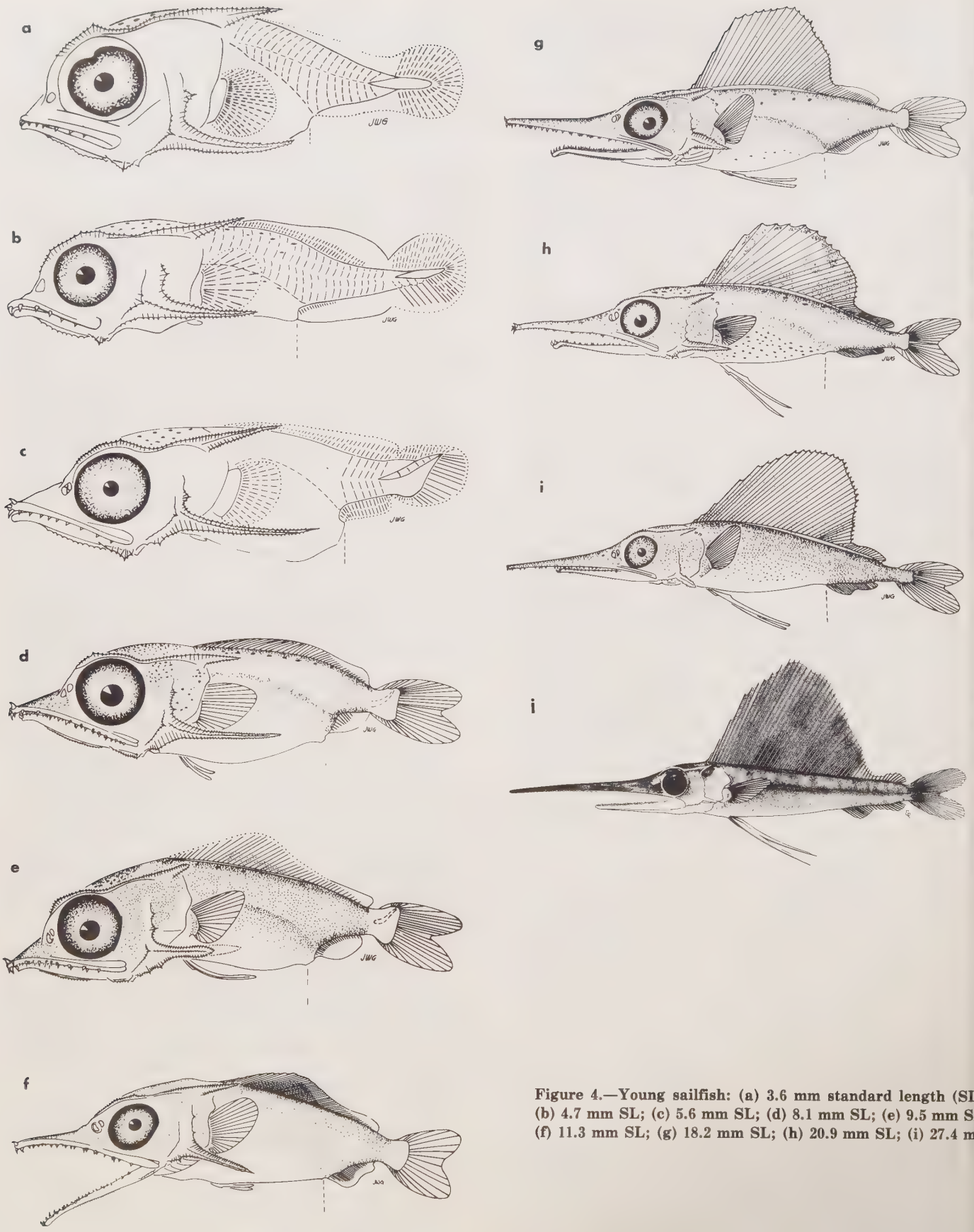
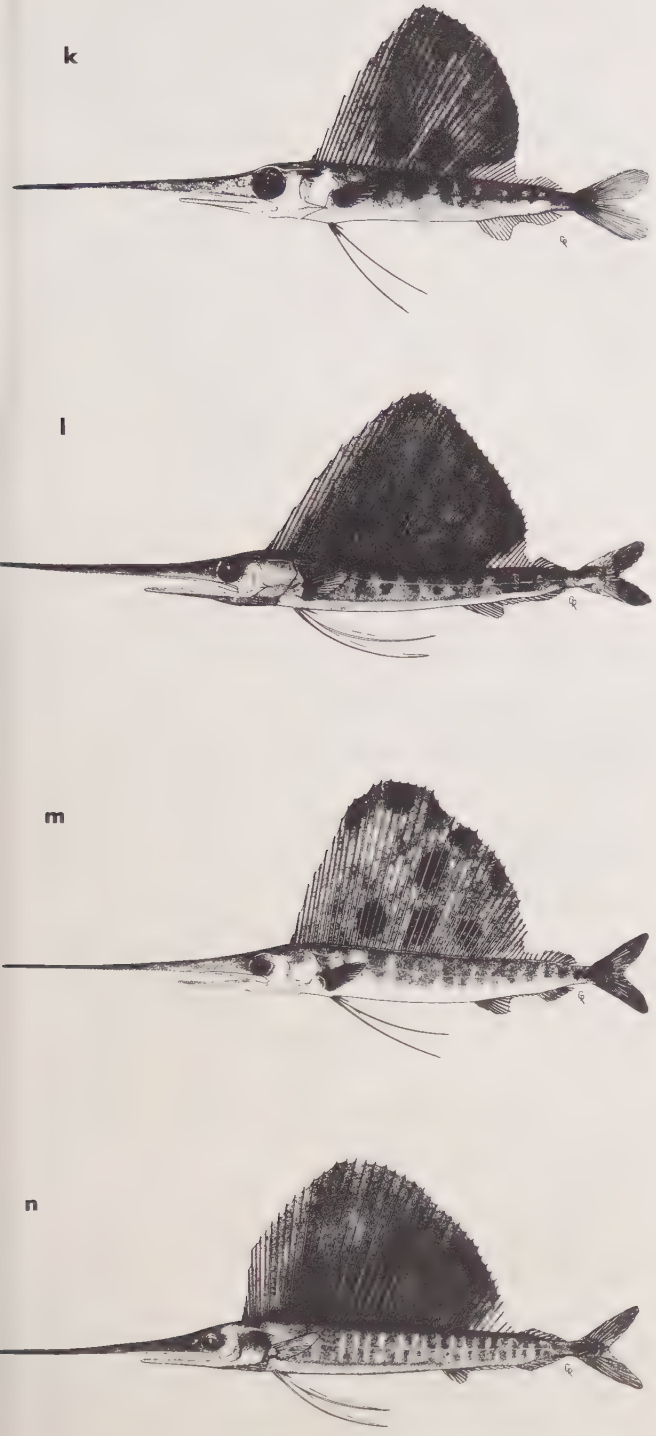


Figure 4.—Young sailfish: (a) 3.6 mm standard length (SL); (b) 4.7 mm SL; (c) 5.6 mm SL; (d) 8.1 mm SL; (e) 9.5 mm SL; (f) 11.3 mm SL; (g) 18.2 mm SL; (h) 20.9 mm SL; (i) 27.4 mm



; (j) 37.1 mm SL; (k) 55.1 mm SL; (l) 98.9 mm SL; (m) 155
SL; (n) 216 mm SL (from Gehringer, 1956, 1970).

of marked differences from their respective adults, generally speaking, in their morphological characteristics. This is particularly true with those of very early stage before the snout develops its specific characteristics. However, the specific separation of the larvae is possible throughout their entire range mainly on the basis of their head profile.

Following are the criteria for identification:

(1) *Larvae under 5 mm in length*: The characters, as shown in Table A [Table 2], can be used for specific separation, although snout length does not provide a useful clue.

(2) *Larvae between 5 and 10 mm in length*: Besides the criteria given in Table A [Table 2], snout length and size of eyes can be used. Black marlin larvae are recognized by their snout. . . . The ratio of snout length to diameter of orbit is largest in sailfish, smallest in black marlin, and is between in shortnosed spearfish. More precisely, the ratio tends to be >1 in sailfish, <1 in black marlin, and $=1$ in shortnosed spearfish in specimens 7—8 mm length.

(3) *Larvae between 10 and 20 mm in length*: They are grouped into two on the basis of their snout length; the long snout group with shortnosed spearfish, sailfish and striped marlin, and the short snout group with black marlins. In the former, the snout length exceeds 1/5 of their body length, while in the latter, it does not. For the specific separation of the former group, Table A [Table 2]; shortnosed spearfish is distinguishable by black chromatophores on brachiostegal membrane, while sailfish is separated from striped marlin by the difference of their head profile: Unlike striped marlin with a straight snout, sailfish has a beak-like snout. And because of this difference in the shape of the snout, they are separable by the difference of the location of snout in terms of the center of eyes. In sailfish, the center of eyes is above the tip of snout, while in striped marlin, they are on a nearly same level.

Separation of white marlin from black marlin can be made on the basis of the form of the pectoral fin.

(4) *Larvae over 20 mm in length*: On top of the criteria of Table A [Table 2], the following characters, as listed in Table B [Table 3], can be applied.

In addition to the above, the distance between anus and the first anal fin insertion works as a reference to discriminate shortnosed spearfish. The distance of the said species is larger, as compared with other species.

The vertebral formulae are also useful tools for separation: the formulae of shortnosed spearfish, sailfish and striped marlin are all 12+12, while those of black and white marlin are 11+13.

Ueyanagi (1964) discussed some of the misidentifications of sailfish larvae made by Sun (1960). He stated that Sun's specimen No. 3 (Fig. 5c; 19.1 mm total length) and No. 4 (Fig. 5d; 30.5 mm total length) seem to be blue marlin. Ueyanagi (1959) pointed out that the larvae identified tentatively by Gehringer (1956) as *Tetrapturus belone* are probably blue marlin. He added that Gehringer's (1956) sailfish figures 6, 10, and 14 closely resemble striped marlin young and hence may be the larvae of the Atlantic cognate of striped marlin, namely white marlin, *T. albidus*.

Little is known on the biology of young sailfish.

Table 2.—Summary of the prominent diagnostic characters of istiophorid larvae less than 5 mm in length (from Ueyanagi, 1964).

Species characters	*Tetrapturus angustirostris*	*Istiophorus orientalis*	*Makaira mitsukurii*	*Eumakaira nigra*	*Marlina marlina*
Profile of head	Tip of snout is lower in level than center of eye.	Same to the left.	Tip of snout and center of eye are on a nearly equal level.	Tip of snout is lower in level than center of eye.	Same to the left.
	Anterior edge of orbit does not project forward.	Same to the left.	Same to the left.	Anterior edge of orbit projects forward.	Anterior edge of orbit does not project forward.
Presence or absence of chromatophores on the branchiostegal membrane.	Present	Absent Chromatophores generally present on the peripheral zone of lower jaw membrane.	Absent	Absent	Absent
Pectoral fins	Fins extend along the lateral side of the body and can be readily folded against the side of the body.	Same to the left.	Same to the left.	Same to the left.	Fins stand out from the lateral side of the body at a right angle and cannot be folded against the body without breaking the joint.

Table 3.—Diagnostic characters usable in distinguishing the istiophorid larvae more than 20 mm in standard length (from Ueyanagi, 1964).

Species characters	*Tetrapturus angustirostris*	*Istiophorus orientalis*	*Makaira mitsukurii*	*Eumakaira nigra*	*Marlina marlina*
Number of first dorsal fin-rays	More than 48	[1]43-47	Less than 45	Less than 45	Less than 45
Shape of first dorsal fin	Anterior-high type	Posterior-high type	Anterior-high type	Anterior-high type	Anterior-high type (presumed).
Lateral line	Single	Single	Single	Complex-having branches	Not single(2)[2] (obscure).

[1]This range is estimated from a small number of materials examined, so it seems to become somewhat wider with an increase of materials.

[2]Lateral line pattern is not yet ascertained.

Beebe (1941) reported that they primarily eat copepods. Voss (1953) identified the stomach contents of his specimens and found predominantly copepods and fish larvae. Gehringer (1956) also identified the stomach contents of his specimens and his results are shown in Table 4.

In summary, sailfish less than 10 mm long generally eat copepods, while fish larvae predominate in larger sizes.

3.3 Adult Phase

3.31 Longevity

De Sylva (1957) stated that natural mortality is undoubtedly high, pointing out that off Florida the sport fishery is dependent upon 1- and 2-yr-old fish. Mather et al. (1974) has recorded the recovery of a tagged sailfish that was at liberty for more than 4 yr. The fish was estimated to weigh 21.3 kg when tagged, which according to de Sylva would be about a 2-yr-old. This specimen, therefore, was at least 6 yr old when recaptured.

There is no information available for the Pacific or Indian oceans, although Koto and Kodama (1962) found that the growth rate of sailfish in the East China Sea is similar to that of sailfish in the Atlantic.

3.32 Hardiness

Adult sailfish are probably adaptable to relatively large changes in their environment and in their ability to utilize different food items.

3.33 Competitors

Although sailfish probably compete with many of the large pelagic scombridlike fishes for food and

Table 4.—Stomach contents of specimens from *Theodore N. Gill* collections (from Gehringer, 1956).

Size of fish (mm)	Contents
3.9	5 copepods
5.4	Parts of 9 copepods
6.0	3 copepods; parts of 7 copepods
6.0	7 copepods; parts of 1 fish larva
9.4	2 copepods; parts of 3 fish larvae (heads 1.4 mm)
[1]10.1	1 fish larva,[2] 4.2 mm
10.1	1 copepod; part of 1 fish larva
[1]10.3	1 fish larva,[2] 4.8 mm
[1]10.3	1 fish larva, 6.0 mm; part of 1 fish larva[2]
[1]10.8	4 fish larvae,[2] approximately 5.4 mm
[1]11.3	Part of 1 fish larva (head, 3.0 mm)
[1]11.4	1 fish larva,[2] 6.6 mm; piece of another fish larva
[1]12.3	1 copepod; part of 1 unidentified crustacean; 1 fish larva,[2] 5.1 mm; part of 1 fish larva
[1]12.8	1 fish larva,[2] 7.2 mm
12.8	4 flying fish larvae, 4.8 to 6.0 mm; head of 1 fish larva
[1]13.0	2 copepods; 1 istiophorid larva, 6.0 mm
13.0	1 flying fish larva, 4.8 mm; parts of 2 other fish, one approximately 6.0 mm
[1]13.9	1 flying fish larva, 5.1 mm; 1 fish larva,[2] 7.2 mm
14.6	Part of 1 fish larva (head, 2.1 mm)
15.3	3 flying fish larvae, 3.6 mm; parts of 2 flying fish larvae
16.2	1 istiophorid larva (head, 2.4 mm)
16.9	Part of 1 fish larva (head, 1.8 mm)
16.9	1 fish larva, 8.4 mm
17.8	3 fish larvae, 3.0 mm, 3.6 mm, and 7.2 mm
18.2	1 thin fish larva, 11.4 mm; part of fish larva
20.9	Parts of fish larva
[1]21.0	1 istiophorid larva, 10.2 mm
27.4	Parts of fish larva
[1]34.5	Parts of fish larvae
38.8	8 flying fish larvae, 4.8 to 8.7 mm; 2 fish larvae, 6.3 mm. and 6.6 mm; parts of 3 fish larvae
[1]45.0	Parts of fish larvae
[1]45.0	Parts of fish larvae

[1]Unidentified species.

[2]All fish listed under footnote 2 appear to be identical, and unless otherwise noted, measurements given are of standard lengths.

spawning areas, it is likely that they are relatively unaffected by this competition. Among the billfishes, sailfish and black marlin, *Makaira indica*, are the dominant inshore species in the Pacific (Howard and Ueyanagi, 1965) and undoubtedly compete for food and living space, although black marlin probably utilize larger food items than do sailfish. Royce (1957) examined 11 black marlin captured in the Pacific and found fishes weighing up to 18 kg in the stomach contents as well as remains from other fishes which were probably too large for a sailfish to consume. Dissimilarities in distribution are evident between sailfish and some of the other billfishes. Kume and Joseph (1969a), for example, showed that the centers of abundance of the shortbill spearfish, *Tetrapturus angustirostris*, and the sailfish in the eastern Pacific are widely separated. The shortbill spearfish did not occur in the catches of research vessels fishing within 370-550 km of the coast while the majority of the sailfish were caught within this limit.

Williams (1967) noted that, ". . . in East Africa longline catches of striped marlin were high and of sailfish low, whereas the sport fishery catches of striped marlin were low and of sailfish very high." Williams suggested that this was partly due to the different habits of the two species. Similar results were obtained by Merrett (1968a, 1971) from the same area, indicating that the sailfish was the most coastal of the five istiophorid species present in the equatorial western Indian Ocean.

In the Atlantic, however, Wise and Davis (1973) showed that during certain seasons of the year, centers of sailfish abundance coincide with centers of white marlin, *T. albidus*, and blue marlin, *M. nigricans*, abundance. Fox (1971) also indicated that sailfish and blue marlin distributions show a strong overlap.

3.34 Predators

There is little information about predation on adult sailfish. Baughman (1941a) reported on the sighting by another observer of a school of bottlenose porpoise, *Tursiops truncatus*, attacking and apparently consuming an adult sailfish in the Gulf of Mexico. Maéda (1967) stated that killer whales attack "marlins," a category which undoubedly includes sailfish. He added, however, that "marlins" are probably not preyed upon to any great extent. Merrett (1968a) commented that shark attacks on fishes hooked on longline gear are well known, but predation on free-swimming tunas and billfishes would be considerably less.

3.35 Parasites, diseases, injuries, and abnormalities

Silas (1967) and Silas and Ummerkutty (1967) summarized previous accounts of parasites of scombroid fishes (Table 5). Williams (1967) stated that he found thousands of euryphorids (copepods, Caligoidea) up to 10 mm in length on the skin of sailfish near the head and caudal areas. He also recorded a heavy infestation of ascarid nematodes in the stomach of one specimen. Ward (1954) listed the helminth parasites *Bothriocephalus manubriformis* (Linton), *Contracaecum histiophori* Yamaguti, and *Hirudinella marina* Garcin as occurring in the viscera of sailfish from Florida waters. Jones (1971) reported on crater wounds caused by the squaloid shark, *Isistius brasiliensis*, in istiophorids.

Billfish are often found with portions of their bill broken off. Marlins and swordfish have been reported as attacking vessels and burying their bills in wooden planking. Sailfish, however, are apparently not as

Table 5.—List of parasites found on sailfish (adapted from Silas, 1967, and Silas and Ummerkutty, 1967).

Locality	Parasite	Location on host
Monogenetic trematodes (Silas, 1967)		
Japan and Sri Lanka	*Capsala ovalis* (Goto)	body surface
West coast of Sri Lanka	*Capsala megacotyle* (von Linstow)	body surface
Japan	*Capsaloides sinuatus* (Goto)	gills
Digenetic trematodes (Silas, 1967)		
Japan	*Hemiurus sardiniae* (Yamaguti)	stomach
Cestodes (Silas, 1967)		
N.W. Atlantic	*Bothriocephalus manubriformis* (Linton)	intestines
Copepods Silas and Ummerkutty (1967)		
Japan	*Caligus quadratus* Shiino	?
?	*Caligus* sp. (Silas and Ummerkutty	behind eye
Pacific off Mexico	*Gloiopotes costatus* Wilson	body surface
Gulf of Mannar	*Gloiopotes longicaudatus* (Marukawa)	body surface and inside gill cover
Sri Lanka	*Gloiopotes watsoni* (Kirtisinghe)	body surface
Pacific off Mexico	*Pennella filosa* (Linnaeus)	buried in body
Sri Lanka	*Pennella instructa* (Wilson)	body surface
Formosa	*Pennella* sp. Ho	buried in body

guilty of aggressive behavior of this type as are marlins and swordfish.

Evans and Wares (1972) examined stomachs from 151 sailfish captured in the eastern Pacific and found 22% with stomach ulcers. They suggested that injuries from the spines of prey fishes were factors in the ulcerations.

3.4 Nutrition and Growth

3.41 Feeding

One of the most detailed accounts of sailfish feeding is found in Voss (1953):

> Apparently no feeding was done at night for in the early morning the fish were scattered. Around 9:00 the first schools began to appear as the sailfish, numbering from 6 or 8 to 25 or 30 began to mill about small groups of "pilchards," forcing them into compact schools by slowly circling about them at the surface, their sails half raised. While feeding the sailfish were oblivious to their own danger and a boat could be eased down into the mass of circling fish until often the sailfish would actually bump against the sides of the vessel. . . .
>
> At short intervals, while the "pilchards" were kept bunched up by the circling sailfish, a single sailfish would break out of the circle and swim rather slowly directly through the small school of "pilchards," thrashing vigorously sideways with its bill, hitting fairly large numbers of the small fish stunning or killing them. After thrashing through the school, the sailfish would then turn, swim slowly downward beneath the school where it would then swim about picking up the dead "pilchards" as they sank downwards.

Voss added that in normal feeding, sailfish were relatively slow in their actions and bursts of speed were exceptions. He concluded that accounts of sailfish being fast swimmers were exaggerated and that speeds of over 13 knots were probably unusual.

3.42 Food

It has been fairly well established that the food of very young sailfish consists primarily of copepods (Beebe, 1941; Voss, 1953; Gehringer, 1956) (see 3.23). Voss noted that with only a few millimeters increase in size, the diet of young sailfish changed to predominately fishes. Gehringer (1956) stated that in the 32 larvae he examined from the South Atlantic coast of the United States, fish were a major portion of the diet in all larvae above 6.0 mm. He also noted that no copepods were found in sailfish above 13.0 mm long (15 specimens). The food of sailfish from the eastern and western Atlantic, off the West African shelf and off northeast Brazil, was examined by Ovchinnikov (1970), who gave a list of food items taken from the stomachs of sailfish from both areas. He stated that the composition of food from eastern Atlantic fish altered according to the season. He reported that in February the food was mainly cephalopods, anchovies, and *Otoperca*, whereas in April sailfish fed on *Sardinella* and in May jack mackerel. He indicated that forage resources were more scant in the open ocean with about half of the stomachs examined being found empty. The qualitative composition of the food was also different, squid and gempylids being the main items.

The above confirms what appears to be a general consensus that although fish and squid form the major portion of their diet, adult sailfish are fairly opportunistic feeders and eat whatever happens to be present. Nakamura (1949) stated that billfishes in general probably do not have any particular tastes in food and probably feed on whatever was abundant in the area or what could be most easily seen or caught. He added that billfish definitely did not feed on demersal organisms although they did feed occasionally on deep-sea fishes. He also stated that it is more reasonable to believe that deep-sea fishes are eaten at night when they approach the surface rather than billfishes diving deep to feed during the day. Ovchinnikov (1970) presented data on the degree of stomach fullness of sailfish off the West African shelf, which in-

dicated that they fed most intensively during the evening hours. Again, judged on the degree of stomach fullness, he found that they fed most intensively at the beginning of February, in the second half of April, and in May. He observed that this sporadic intensity of feeding was correlated inversely with periods of intensified spawning.

Evans and Wares (1972) found mostly squid and fishes in stomachs from sailfish captured in the eastern Pacific. Voss (1953) stated, however, that sailfish often feed on typical bottom dwellers such as sea robins (Triglidae) and gastropod mollusks (Table 6). He also added that one of the cephalopods, *Grimpoteuthis* sp., found in the stomach contents, is a bottom dweller from rather great depths. Baughman (1941a, b) stated that sailfish examined from the western Gulf of Mexico contained a large proportion of shrimp in their stomachs.

3.43 Growth rate

Sailfish apparently have a very rapid growth rate. De Sylva (1957) studied the growth of sailfish in the Florida region based on length frequencies of almost 9,000 young and adult sailfish. He stated that sailfish average a total length of 17.8 cm at the end of their first month, 50.8 cm by the end of the second month, 89 cm by the end of the third month, and 111.7 cm at the end of 4 mo. He added that there was considerable variation in these lengths due to variation in time of spawning and subsequent variation in availability and abundance of planktonic food. By the end of their first year of life sailfish average 183 cm in total length, 216 cm the second year, and 233.7 cm by the end of the third year. De Sylva noted that determination of age after 2 yr was difficult. Variation in weight is large; a 3-yr-old fish with a modal length of 233.7 cm may vary in weight from 19 to 49.4 kg. Jolley (1974) suggested the possibility of differential growth between male and female Atlantic sailfish. This hypothesis partially explains the wide variation in weight and length at a given age described by de Sylva. Jolley showed significant differences between the length-weight relationship of males and females.

Koto and Kodama (1962) estimated growth of sailfish from the East China Sea. Their growth rates for categories "n, $n+1$, $n+2$" were similar to those estimates by de Sylva for 1-, 2-, and 3-yr-old fish. Koto and Kodama also noted marked seasonal changes in growth rate with a maximum from June to December.

Williams (1970) discussed growth of sailfish off the coast of East Africa, and although his data were too few for a detailed analysis of growth, he noted that based on de Sylva's work the majority of the sailfish caught off East Africa were 3 yr old or older. He stated that sailfish in the Indian and Pacific oceans undoubtedly grow larger than Atlantic sailfish and this could be due to a longer life span or some other feature of growth.

Table 6.—Stomach contents of 241 adult specimens of the sailfish, *Istiophorus americanus* (from Voss, 1953).

Specimens	Number	Total
Scombridae (mackerels, etc.)		59
Euthynnus alletteratus (little tuna or false albacore)	35	
Acanthocybium solanderi (wahoo)	1	
Scomberomorus (regalis (?) painted mackerel)	1	
Hemiramphidae (halfbeaks)		42
Hemiramphus sp. (*brasiliensis*?) balao	16	
Exocoetidae (flying fish)		6
Cypselurus heterurus (Atlantic flying fish)	1	
Belonidae (needlefish)		25
Ablennes hians (flat needlefish)	2	
Strongylura notatus (common needlefish)	5	
Trichiuridae (cutlassfish)		14
Trichiurus lepturus (cutlassfish)	13	
Monocanthidae (filefish)		2
Monocanthus hispidus (common filefish)	2	
Tetradontidae (swell or blowfish)		1
Lagocephalus laevigatus (rabbitfish)	1	
Mugilidae (mullet, some undoubedly bait)		10
Mugil cephalus (black mullet)	1	
Mugil trichodon (silver mullet)	1	
Mugil curema (silver mullet)	3	
Priacanthidae (Bigeye)		1
Priacanthus sp. (catalufa)	1	
Clupeidae (herrings)		19
Sardinella anchovia (Spanish sardine)	11	
Engraulidae (anchovies)		2
Carangidae (jacks)		43
Decapterus macarellus (mackerel scad)	7	
Caranx ruber (blue runner)	9	
Oligoplites saurus (leather jacket)	3	
Sparidae (porgies)		12
Lagodon rhomboides (pinfish)	12	
Balistidae (triggerfish)		2
Balistes (forcipatus?) (spotted triggerfish)	1	
Balistes carolinensis (common triggerfish)	1	
Coryphaenidae (dolphins)		1
Coryphaena hippurus (dolphin)	1	
Triglidae (sea robins)		1
Pomatomidae (bluefish)		2
Pomatomus saltatrix (bluefish)	2	
Gerridae (mojarras)		1
Gadidae (cod)		1
Myrophidae (worm eel)		1
Unidentifiable fish		138
Cephalopoda (octopods and squid)		77
Octopoda (octopods)		
Argonautidae (paper nautilus)		
Argonauta argo (paper nautilus)	15	
Argonauta sp. (*hyans*?)	1	
Stauroteuthidae		
Grimpoteuthis (?)	11	
Decapoda (squid)		49
Ommastrephidae		
Sthonoteuthis bartrami (flying squid)	29	

3.5 Behavior

3.51 Migrations and local movements

Sailfish perform long-range migrations of thousands of miles as well as fairly extensive short-term movements most likely based on local environmental conditions.

Mather et al. (1974) reported on the results of 18 yr of billfish tagging under the Woods Hole Oceanographic Institution Cooperative Gamefish Tagging Program. Over 12,000 sailfish were tagged and 95 recoveries were recorded (Table 7). The longest distance between release and recovery was from off Cape Hatteras, N. C., to just north of Surinam, a distance of over 1,853 km (Fig. 5). The longest time at large was over 4 yr. Voss (1953) believed that there is a population of sailfish present off Florida all year long, but in summer with the extension of warm water northward there is a movement of sailfish northward along the inside edge of the Gulf Stream. With the arrival of the winter northerlies these fish are driven southward to regroup off the coast of Florida.

Squire (1974) reported on the results of a billfish tagging program in the eastern Pacific from 1954 through 1971. Over 4,700 sailfish were tagged; only 8 were recovered. Most recaptures were near the tagging locality and the longest period at large was 15 mo.

Nakamura et al. (1968) stated that sailfish in the western Pacific migrate from New Guinea, the Solomon Islands, and the Philippines along the Japanese Current to Japan and the Pacific coast of Mexico. In autumn sailfish enter the warm Tsushima Current and move into coastal waters where they are sometimes captured in traps. In the East China Sea, Koto et al. (1959) reported that sailfish migrate northward in summer and return southward in autumn where they overwinter in the southernmost area. They also reported that fish under 160 cm long move into the area between May and July while fish over 160 cm move southward out of the area, probably for spawning.

In the Indian Ocean, Williams (1970) and Merrett (1971) discussed the movements of sailfish off the coast of East Africa. Williams believed that there are two overlapping migratory patterns, one a localized onshore-offshore migration with a superimposed migration from the north and northeast with the intrusion of the Somali Current. Merrett believed that the onshore migration was a postspawning, feeding migration.

3.52 Schooling

Sailfish occasionally form schools or groups of from 3 to 25 or 30 individuals. More often, however, concentrations of sailfish occur in loose aggregations over a broad area. Large numbers of sailfish occur off the southeast coast of Florida during the winter months. Voss (1953) reported that in early morning sailfish off the Florida coast were scattered, but by 0900 schools of up to 30 fish began to form and feed on concentrations of small forage fish.

Furukawa (1961) presented a method of calculating the size of an average school or aggregation using the

Table 7.—Releases for Atlantic sailfish, *Istiophorus albicans*, in the western North Atlantic by years, and returns from these by months at liberty (from Mather et al. 1974).

Releases		Months at liberty								
Year	Number	0-0.9	1-1.9	2-5.9	6-11.9	12-17.9	18-23.9	24-35.9	36-47.9	Totals
1954	27									
1955	16				1					1
1956	0									
1957	24									
1958	28				1	1				2
1959	113									
1960	827		2	1	1	1				5
1961	1,157	1		1	2	2				6
1962	1,284	2	1	1	5	1				10
1963	1,162	3	1	4	1					9
1964	1,080	2	2	1	1					6
1965	1,093	2	1	2	3	1				9
1966	1,139	5		4	4		2	1	1	17
1967	828	2	2	7	1	1				13
1968	775	3	1	1	3	1	1			10
1969	763	1	1	2		1				5
1970	621	1								1
1971	1,068				1					1
Total	12,005	22	11	24	24	9	3	1	1	95

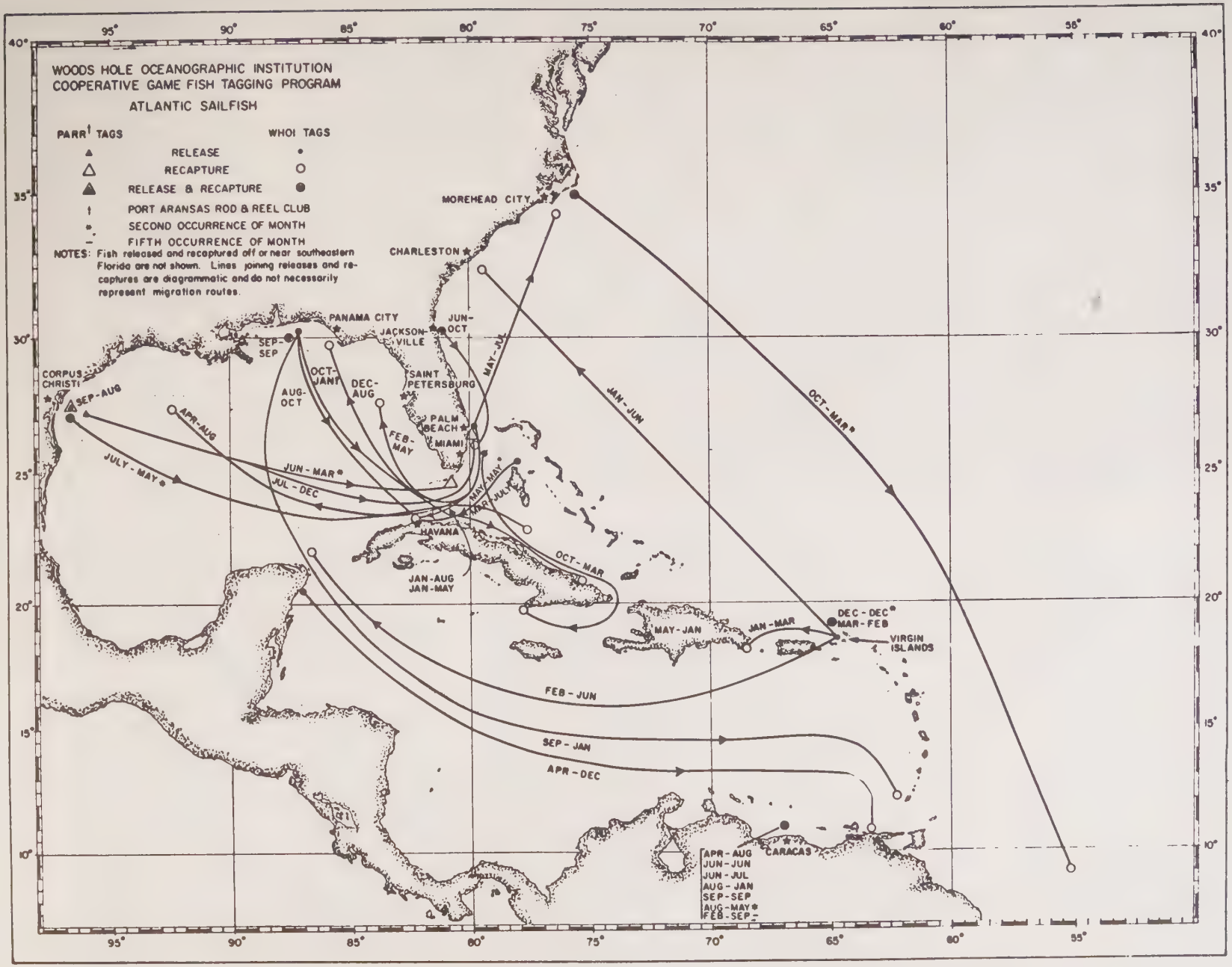


Figure 5.—Releases and recaptures of sailfish in the North Atlantic Ocean (from Mather et al., 1974).

number of sailfish caught by one longline. His estimates for the East China Sea and for the Okinawa region were 2,462 and 624, respectively, which was less than for striped marlin or black marlin but greater than for blue marlin or swordfish.

Ovchinnikov (1970) reported a high degree of schooling in sailfish off West Africa from the frequency of occurrence on neighboring hooks along a tuna longline. He found percentage catches on adjacent hooks extremely high; often sailfish were caught, or lost, from every hook for a length of several kilometers.

4 POPULATION

4.1 Structure

4.11 Sex ratio

Ueyanagi et al. (1970) examined 353 sailfish from the Atlantic and found 208 females and 145 males, and Nakamura (1971) also reported on predominance of females in the Gulf of Mexico sport fishery. He examined 81 sailfish over a period of 4 yr and found an overall ratio females to males of 2.4:1.

Nakamura (1949) stated that the sex ratio of sailfish in the East China Sea area was about even and did not change greatly throughout the year. Williams (1964) found a sex ratio males to females of 3.25:1 in 17 specimens captured by longline gear off East Africa. He later (Williams, 1970) examined sport catches off Malindi, Kenya, and found a sex ratio males to females of 2:1. Merrett (1971) examined 79 sailfish caught by longlines off East Africa and found males predominating, although not as greatly as in Williams' sample. In the inshore troll fishery, Merrett noticed no significant deviation from a 1:1 ratio.

4.12 Age composition

De Sylva (1957) concluded from his analysis of age and growth of sailfish off southern Florida that most of the population consisted of fish less than 3 yr old. He stated that the winter sport fishery is almost entirely dependent upon fish which are about 6 and 18 mo old. In the summer, the majority caught are 1- and 2-yr-old fish.

Williams (1970) stated that if growth rates for the Atlantic and Indian oceans were similar, then the majority of the sailfish caught off Kenya are over 3 yr old. He believed that the single mode in length frequencies of sailfish caught off East Africa undoubtedly included at least two successive year classes. Williams added that growth rates may not be similar, however, and the larger sizes of Pacific and Indian ocean sailfish may indicate much longer life or some other factor.

4.13 Size composition

De Sylva (1957) examined length frequencies of over 9,000 sailfish from off southern Florida (Fig. 6). The majority of the sport catch range from about 102 to 140 cm trunk length (posterior edge of the orbit to the anterior insertion of the caudal keels) or 173 to 229 cm total length (tip of upper jaw to vertical line drawn between tips of caudal lobes) with a wide range in weight from 6.0 to 49.4 kg. The second largest group is from 61 to 94 cm trunk length averaging under 6 kg. The small fish begin to appear in the catch in late summer, becoming prominent in November, December, and January. De Sylva stated that these fish are the incoming year class.

Ueyanagi et al. (1970) found a unimodal distribution in length frequencies of sailfish caught on longlines in the Atlantic. The majority were from 125 to 165 cm body length (from posterior edge of orbit to centralmost caudal rays). The largest sailfish caught by sport fishing gear from the Atlantic is a 55.8-kg specimen caught off the Bahamas in 1950.

Williams (1970) found a unimodal distribution in length frequencies of sailfish caught in the sport fishery at Malindi, Kenya (Fig. 7). The majority ranged from 203 to 254 cm fork length (tip of snout to central rays of the caudal fin) or from 224 to 279 cm total length (same as de Sylva's total length) with a weight range of from 18.1 to 47.2 kg. Williams reported that the Kenya record for 1957 weighed 62.1 kg. Merrett (1971) examined 77 sailfish caught on longlines off East Africa. He also found a unimodal distribution with the majority of the specimens between 160 and 185 cm body length (center of orbit to tip of shortest caudal ray).

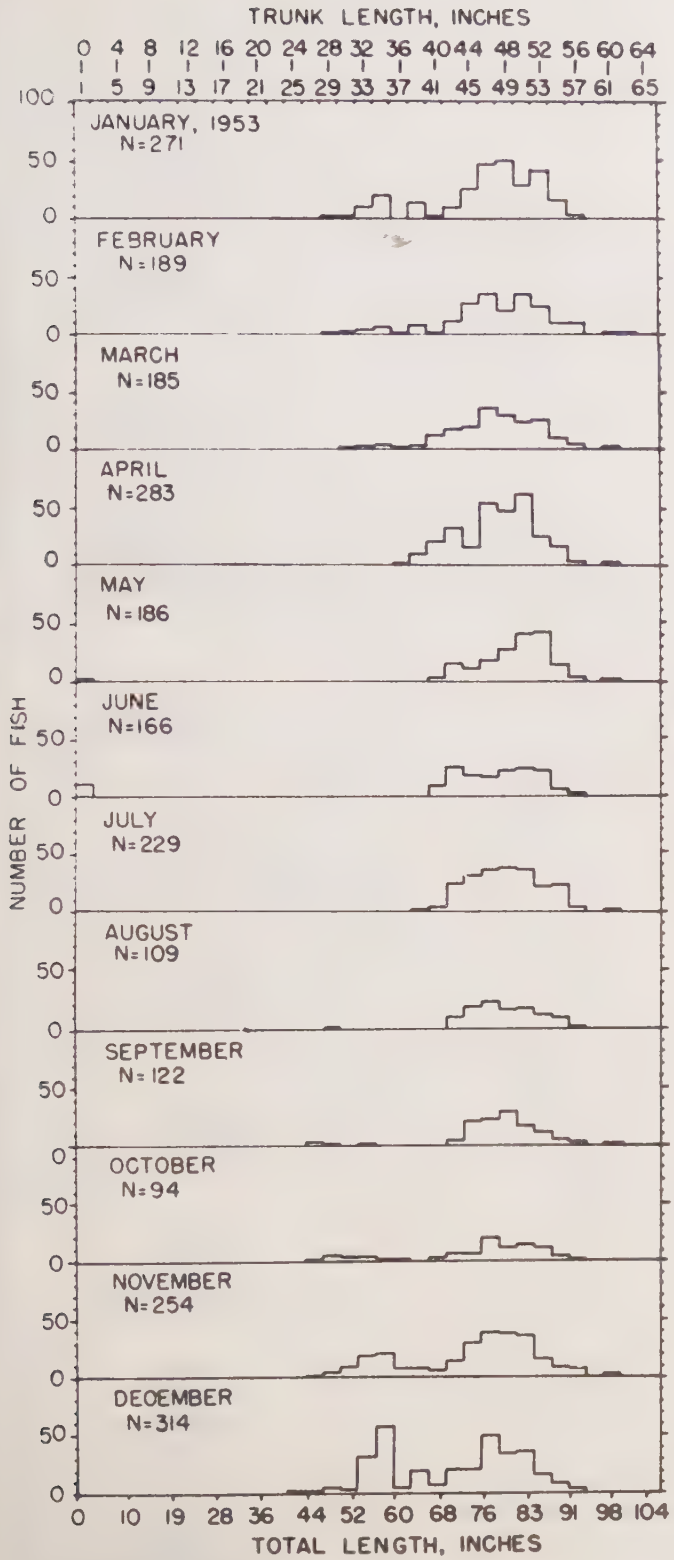
Koto et al. (1959) presented length frequencies of sailfish caught by longlines in the East China Sea (Fig. 8). Size ranged from 105 to 240 cm body length (tip of lower jaw to central rays of caudal fin). Sixty percent were from 165 to 190 cm body length. The distribution is essentially unimodal except in June when a group of 125 to 150 cm fish suddenly appeared in the catch. Koto et al. believed that these small fish enter the East China Sea from other areas during this month. The largest sailfish recorded on sport fishing gear in the Pacific is a 100.2-kg specimen caught near the Galapagos Islands in 1947.

Length-weight relationships have been reported by de Sylva (1957), Merrett (1968b, 1971), Kume and Joseph (1969b), Williams (1970), Nakamura (1971), and Jolley (1974). These results are summarized in Table 8. None but Jolley were able to detect any differences between sexes. Nakamura (1949) stated that sex differences, if any, were inconspicuous in Pacific sailfish.

4.2 Abundance and Density (of Population)

4.21 Average abundance

Nothing found in the literature.



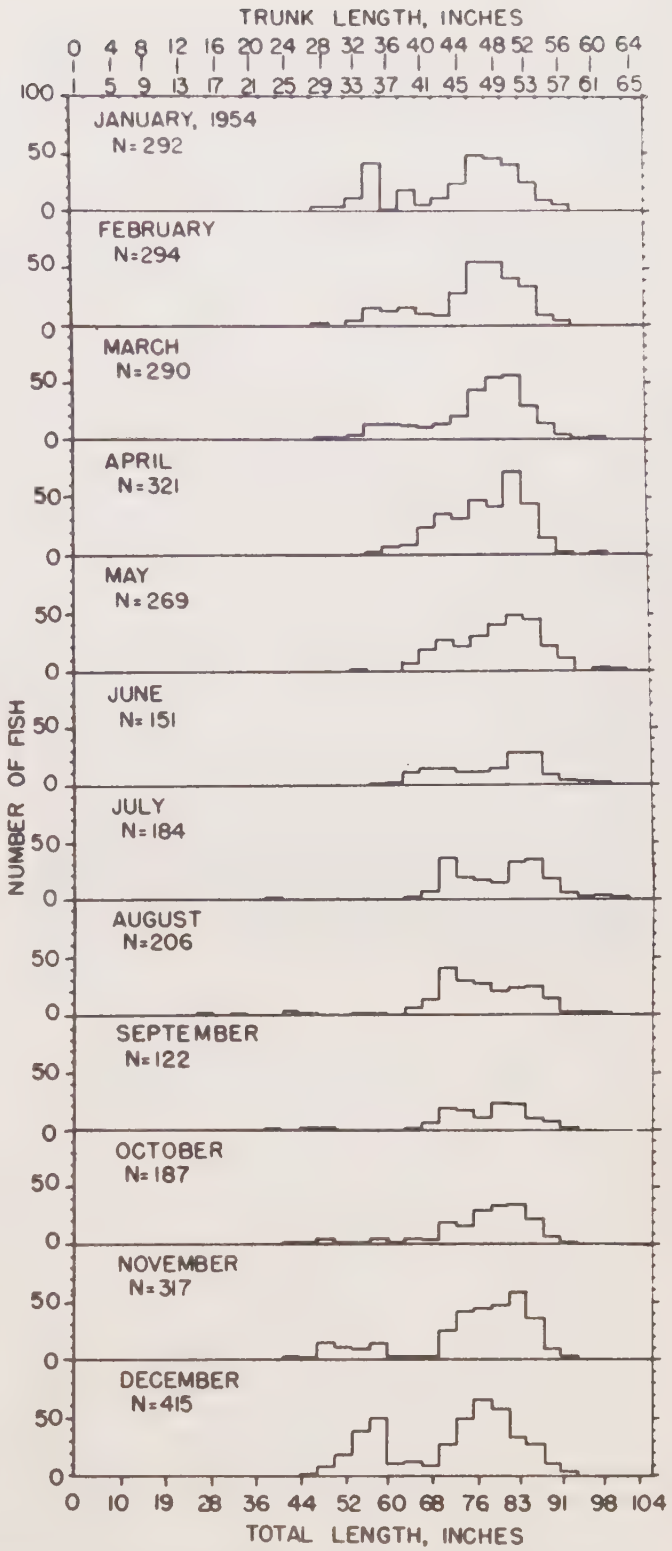


Figure 6.—Left, length-frequencies for Atlantic sailfish from southern Florida, 1953. Right, length-frequencies for Atlantic sailfish from southern Florida, 1954 (from de Sylva, 1957).

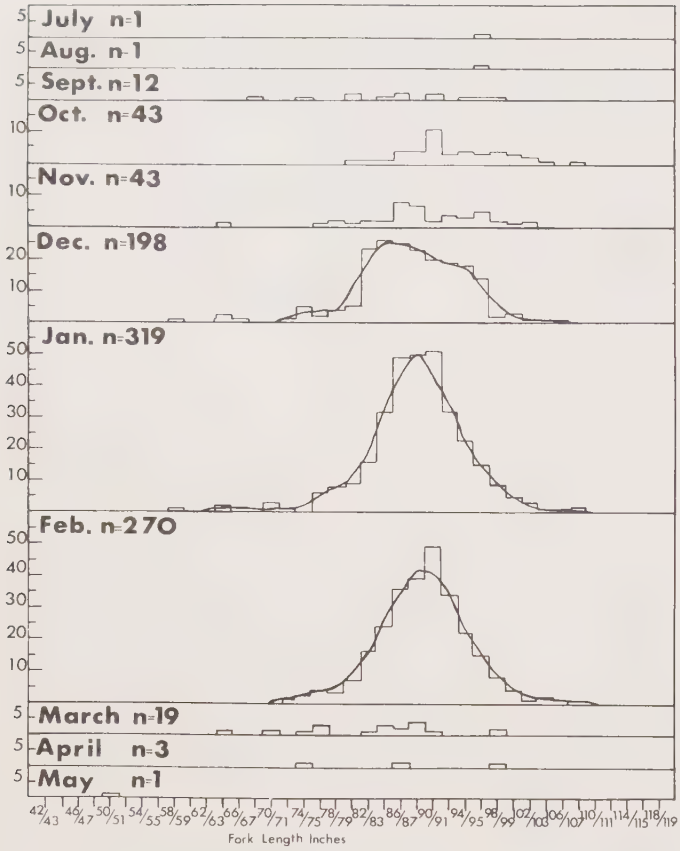


Figure 7.—Monthly length-frequencies of sailfish from Malindi, Kenya, pooled for the four seasons from 1958 through 1962. (Smoothed curves from three figure moving average.) (From Williams, 1970.)

Table 8.—Length-weight relationship of sailfish, *Istiophorus platypterus*.

Author	Measurement	Range	Log *a*	Log *b*
Merrett (1968b)	Eye-fork length in centimeters, weight in pounds	126-194 cm	-4.459	2.819
Kume and Joseph (1969b)	Eye-fork length in centimeters, weight in kilograms	134-205 cm	-3.9357	2.4156
Williams (1970)	Tip of snout to fork in inches, weight in pounds	60-100 inches	-2.1458	1.8896
Nakamura (1971)	Total length in inches, weight in pounds	70-110 inches	-4.68194	3.26326
Jolley (1974)	Trunk length in centimeters, weight in kilograms	70-144 cm (males)	-5.784	3.342
		42.5-151.5 cm (females)	-4.941	2.950

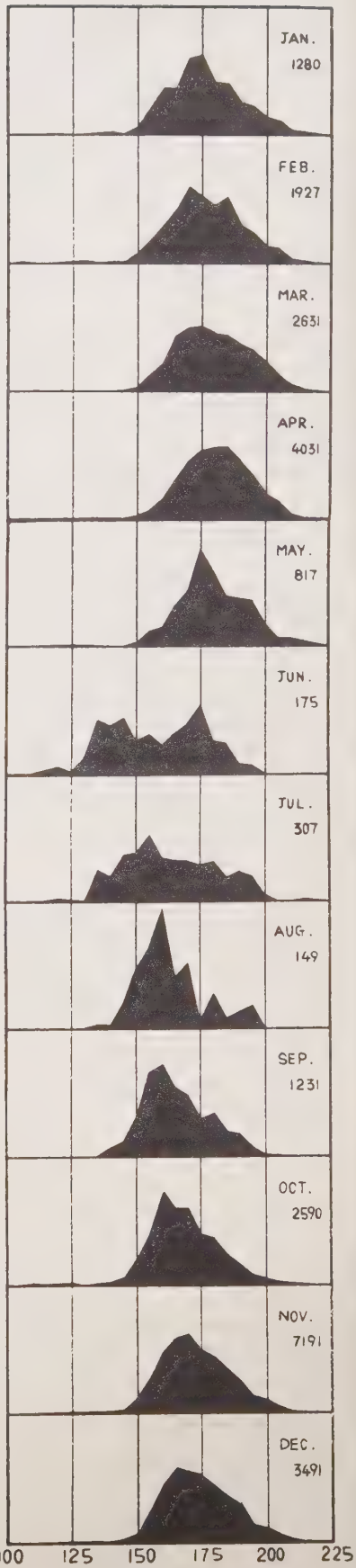


Figure 8.—Body length composition of sailfish in the East China Sea, by month from (Koto, Furukawa, and Kodama, 1959).

4.22 Changes in abundance

Changes caused by hydrographic conditions are referred to in general terms in 2.3.

4.23 Average density

Howard and Ueyanagi (1965) indicated catches of *I. platypterus* by the number caught per tuna longline operation (approximately 2,000 hooks) for a composite year in the Pacific Ocean. In oceanic fishing operations the catches are shown to be generally 1.1-5.0 fish per operation while closer to land masses the average density was approximately 5.1-10.00 fish per operation in areas commonly fished by Japanese longliners.

For comparison, an average hook-rate of 0.168 sailfish per 100 hooks was obtained from 154 longlining operations in the equatorial western Indian Ocean during 1964-67 (Merrett, 1971). This figure is similar to that (0.14 for 100 hooks) obtained by Williams (1967) during an earlier survey.

4.24 Changes in density

Kume and Joseph (1969a) showed that heavy longline fishing had affected the apparent abundance of sailfish in the waters off Central America. The initial hook-rate in 1964 was 10.6 per 100 hooks, 9.5 the following year, and 5.8 in 1966.

Williams (1970) examined the catches of a sport fishery in the equatorial western Indian Ocean off the Kenya coast from 1958-68 and his results are shown in Figure 9. He indicated that, with effort relatively stable, the catch and catch per unit effort (CUE) paralleled one another over the 10-yr period. He pointed out, however, that while the CUE and catches have increased since 1962, there was a sharp decline in the mean (and median) weight of fish caught.

Kume and Joseph (1969a) indicated the seasonal trends in density reflected by the catches of sailfish within 370-550 km of the coast in the tropical eastern Pacific. They showed that in the northern hemisphere the area of highest sailfish abundance is between Guatemala and the mouth of the Gulf of California. In the area around central Mexico sailfish appear abundant all year; during the first quarter this is the only area where they are. During the second quarter, there appears to be a southerly extension of the area of high abundance to as far south as lat. 10°N. This is maintained during the third quarter as well as a northward movement of fish to about lat. 20°-22°N. By the fourth quarter they reported a northward shift in the southern limit to about 15°N and in the northern limit to about lat. 25°N.

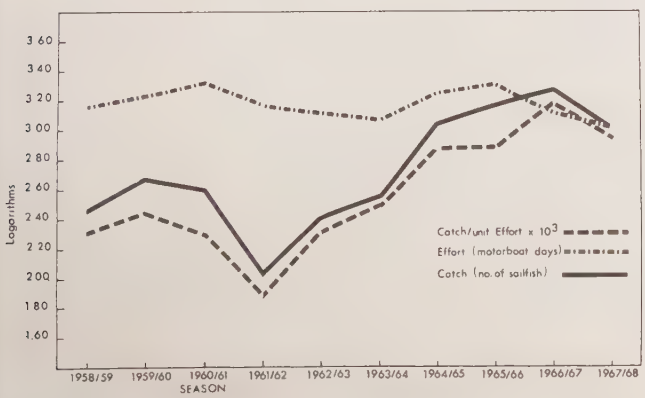


Figure 9.—Sailfish effort, catch, and catch per unit effort for the 10 seasons from 1958 through 1968 at Malindi, Kenya (from Williams, 1970).

Evidence of seasonal changes in density of sailfish in the equatorial western Indian Ocean was given by Williams (1967, 1970) and Merrett (1968a, 1971). In the tuna longline survey off the East African coast during 1958-60, Williams (1967) found a mean hook-rate of 0.01 per 100 hooks during the southeast monsoon (April-October) while in the northeast monsoon (November-March) it rose to 0.31 per 100 hooks. Continuing this survey (1964-67) in a wider area of the equatorial western Indian Ocean, Merrett (1971) confirmed the earlier results by obtaining hook-rates of 0.11 per 100 hooks during the southeast monsoon and 0.35 per 100 hooks during the northeast monsoon. Williams (1970) indicated more specifically the seasonal variation in density off the Kenya coast. He showed that, with few exceptions, sailfish are restricted to the period October to March, with peak catches coming in December and January. The catches of the latter 2 mo constituted 47.6-77.3% of the seasonal totals.

4.3 Natality and Recruitment

4.31 Reproduction rates

Nothing found in the literature.

4.32 Factors affecting reproduction

Nothing found in the literature.

4.33 Recruitment

According to de Sylva (1957) some sailfish first enter the catches of the sport fishery in the southern Florida area during the winter at an age of about 6 mo. Based upon de Sylva's age determinations, the age of recruits to the East China Sea fishery reported upon by Koto and Kodama (1962) is likely to be approximately 1 yr old (modal size: 140-175 cm). In the sport fishery off Malindi, Kenya, Williams (1970) found a modal size of 249-cm total length (29.5-31.3 kg), which is slightly longer at the same weight than that of a 42-mo-old Atlantic fish. However, he pointed out that this mode may be expected to include at least two successive year classes and that a constant growth

rate over the range of the species is doubtful. Thus, factors affecting recruitment such as growth, predation, and migration act differentially in various stocks of sailfish throughout the world's oceans.

No estimates of recruitment have been found in the literature. Yet in the light of the high growth rate and high natural mortality suggested by de Sylva, it follows that the reproductive rate and recruitment rate should be higher than in slower growing, longer lived species of similar population size.

4.4 Mortality and Morbidity

4.41 Mortality rates

There have been no studies on the mortality of sailfish, although de Sylva (1957) stated that it seemed evident that natural mortality is high off southern Florida based on the fact that only two year classes support the sport fishery.

4.42 Factors causing or affecting mortality

See 3.34.

4.43 Factors affecting morbidity

See 3.35.

4.44 Relation of morbidity to mortality rates

Nothing found in the literature.

4.5 Dynamics of Population (as a Whole)

Nothing found in the literature.

4.6 The Population in the Community and the Ecosystem

There has been no detailed study of the ecology of *I. platypterus* over the whole range of its distribution. However, the direct relation between this species and some of the physical features of the biotope in certain localities have been discussed by Voss (1953), Gehringer (1956), Cadenat (1961), Ovchinnikov (1966, 1970), Williams (1967, 1970), Kume and Joseph (1969a), and Yurov and Gonzales (1971). On a broader basis these features are discussed fully by Parin (1968). The vertical zone of the community in which the sailfish lives is characterized by good illumination and is likely to be delimited below by temperature at the main thermocline (from 10-20 m to 200-250 m, depending on area). Temperature is apparently important also in the latitudinal distribution of the species and some authors, Ovchinnikov (1966, 1970) and Kume and Joseph (1969a), suggested that the 28°C isotherm is optional for the species, while Cadenat (1961) indicated that the increased abundance of sailfish in the inshore waters off the Ivory Coast coincided with approximately this temperature. The association of larval *I. platypterus* with the warm waters of the Gulf Stream was indicated by Gehringer (1956) and of larvae and adults with the Kuroshio Current by Yabe (1953), Ueyanagi (1959), and Howard and Ueyanagi (1965). It is likely that the greatest effect salinity produces on the ecosystem in which sailfish live occurs at the boundaries of surface water masses and other regions in which a rise in salinity occurs simultaneously with a rise in temperature, which produces conditions conducive to high productivity. Aggregations of sailfish in such areas have been shown off West Africa and off the east coast of Brazil by Ovchinnikov (1966, 1970) and by Ueyanagi et al. (1970).

5 EXPLOITATION

5.1 Fishing Equipment

5.11 Gear

The primary commercial fishing gear for sailfish is the tuna longline. Basically, the tuna longline is a drifting horizontal line of considerable length (up to 120 km), from which single-hooked branch lines hang down at regular intervals. The gear and fishing methods are well known and have been described by Yoshida (1966).

Trolling is the primary method used by sport fishermen for catching sailfish and in principal consists of towing a baited hook or lure through the water to simulate a swimming fish. The bait is trolled astern of a motor launch, and the line is loosely connected on its passage inboard to a clip attached at the tip of a laterally directed trolling pole (locally called "tangon" or "outrigger"). When a sailfish strikes the bait, the line snaps free from the clip. This momentarily stops the bait's progress through the water and is supposed to resemble the effect of the preliminary strike on a live fish after which the sailfish turns and swallows the bait.

5.12 Boats

The types of fishing vassels used in tuna longlining have been described, again by Yoshida (1966). No special boat is required by sport fishermen. All that is necessary is one which has an open stern where the angler may stand, a trolling pole on one or both sides, and the power to troll at up to 6 knots. Nevertheless, the design of many modern, sport fishing boats is highly sophisticated, incorporating additional facilities for the fisherman.

5.2 Fishing Areas

5.21 General geographic distribution

See 5.22.

5.22 Geographic ranges

Although incidental in tuna longline catches throughout the Atlantic and Indo-Pacific oceans, sailfish are specifically sought around the edges of the continental shelf in many tropical areas of the world. The most important fisheries are concentrated in southeastern Florida; the northern and northeastern Gulf of Mexico; the Bahamas; the Caribbean region; Venezuela; the eastern tropical Pacific between Southern California and Chile; Hawaii; New Zealand; eastern Australia; Kenya to Cape Town; South Africa and Ghana to Senegal.

Since sport fishing is a leisure activity, the areas of maximum fishing effort may or may not coincide with the areas of greatest density of sailfish. Within the distributional range of sailfish, some areas of greatest fishing intensity may be correlated with the density of human population on the adjacent land mass. The seaward extent of the fishery is similarly affected by the desires of the angler. Thus, in most cases, the range is governed by the optimum distance offshore which can be attained during a day trip.

5.23 Depth ranges

Merrett (1968a) showed that sailfish are caught with equal frequency on all hooks on a longline which fish at depths from the surface down to about 160 m.

5.24 Conditions of the grounds

Nothing found in the literature.

5.3 Fishing Seasons

5.31 General pattern of seasons

Sailfish are caught during all seasons of the year.

5.32 Dates of beginning, peak, and end of seasons

Sailfish are most abundant in the Atlantic longline catch in spring and summer (Wise and Davis, 1973). The sport fishery in the western Atlantic captures sailfish all year long with best fishing in winter and early spring.

Williams (1970) stated that the best sport fishing for sailfish at Malindi, Kenya, is from October to March with peak catches in December and January.

Howard and Ueyanagi (1965) indicated that in the eastern Pacific sailfish are caught in good numbers off Acapulco all year long, but peak fishing is during the winter months.

5.33 Variation in date and duration of season

Williams (1970) stated that the start and finish of the period of peak abundance of sailfish in the sport fishery at Malindi, Kenya, shows a marked relationship to annual fluctuations in overall environmental conditions in the area.

5.4 Fishing Operations and Results

5.41 Effort and intensity

The oceanic longline fishery, initially a Japanese effort but recently joined by China, Cuba, Republic of Korea, Venezuela, and others, is the primary commercial fishery utilizing sailfish. The unit of effort commonly used in this fishery is number of fish caught per 100, 1,000, or 10,000 hooks fished.

In the Atlantic, peak Japanese fishing effort was in 1965 when more than 97 million hooks were fished, resulting in a catch of 118,000 "other marlins," a category which includes spearfish and sailfish. Catch per 10,000 hooks for this category rose from 39.0 in 1959 to a high of 189.0 in 1967.

Kume and Joseph (1969a) presented data on catches from the eastern Pacific that indicated a high abundance of sailfish in this area. Almost 330,000 sailfish were caught in 1965, and catch per 100 hooks was 9.4. Catch per effort declined from 10.6 per hundred hooks in 1964 to 5.8 in 1966. Total fishing effort in this area declined from a high of 62 million hooks in 1964 to 47 million in 1966.

5.42 Selectivity

Nothing found in the literature.

5.43 Catches

See 5.41.

6 PROTECTION AND MANAGEMENT

6.1 Regulatory (Legislative) Measures

6.11 Limitation or reduction of total catch

The State of Florida has a catch limit of two sailfish per day per person.

6.12 Protection of portions of population

Nothing found in the literature.

6.2 Control or Alteration of Physical Features of the Environment

Nothing found in the literature.

6.3 Control or Alteration of Chemical Features of the Environment

Nothing found in the literature.

6.4 Control or Alteration of Biological Features of the Environment

Nothing found in the literature.

6.5 Artificial Stocking

Nothing found in the literature.

7 POND FISH CULTURE

Not applicable.

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Synopsis of Biological Data on the Mediterranean Spearfish, *Tetrapturus belone* Rafinesque[1]

DONALD P. de SYLVA[2]

1 IDENTITY

1.1 Nomenclature

1.11 Valid name

The valid scientific name of this taxon is *Tetrapturus belone* Rafinesque, 1810. The synonymy of this species has been recently treated by de Sylva (1973) and is reproduced here with slight changes.

1.12 Synonymy

Tetrapturus belone Rafinesque, 1810.

Tetrapturus belone Rafinesque, 1810, Caratteri, p. 54-55, pl. 1, Fig. 1 (original description; type locality: Sicily). Robins and de Sylva, 1963, Bull. Mar. Sci. Gulf Caribb. 13(1):84-122 (redescription; neotype based on a 1,268-mm specimen from Sicily, USNM 196527.

Skeponopodus typus Nardo, 1833, Isis (Oken) 26(4): 416-419 (type locality: Adriatic Sea).

Tetrapterurus belone Bonaparte, 1841, Icon. Fauna Ital. 3(1):19 (emended orthographic spelling of *Tetrapturus* Rafinesque).

Tetrapterus belone Agassiz, 1843, Recherches Poiss. Foss. 5:7, 89-90, table E (emended spelling).

Tetraplurus belone Vérany, 1847, Atti Ott. Riun. Sci. Ital. Genoa, p. 492-494 (Camogli, Ligurian Sea; misprint for *Tetrapturus*?).

Histiophorus belone Günther, 1860, Cat. Fishes 2:513 (new combination).

Scheponopodus prototypus Canestrini, 1872, Fauna Italia (3):112 (type locality: Italy; variation of spelling of *Skeponopodus* Nardo, 1833).

Histiophorus (*Tetrapturus*) *belone* Lütken, 1876, J. Zool. (Gervais) 5:60-63, pl. 3 (*Tetrapturus* a subgenus of *Histiophorus*).

Tetrapturus imperator Goode, 1883, Rep. U.S. Comm. Fish Fish. for 1880: 306-307 (*T. belone* erroneously placed in synonymy of *T. imperator* Schneider, a synonym of and based upon a drawing of *Xiphias gladius*, copied from Aldrovandi).

Makaira belone Tortonese, 1958, Atti Soc. Ital. Sci. Nat. 97(4):330 (new combination).

Tetrapturus beloni [sic] Briggs, 1958, State Mus. 2(8): 287 (erroneously listed from Florida; *non* Rafinesque but *pfluegeri*, as shown by Robins and de Sylva, 1963).

1.2 Taxonomy

The identity of this species has been very uncertain. For example, LaMonte and Marcy (1941:21-22) suggested that *belone* merely represented the young of some other billfish. Lack of specimens precluded determination of the identity of this taxon until Robins and de Sylva (1960), thanks largely to the late Al Pflueger, presented data on 23 western Atlantic specimens which they tentatively identified as *T. belone*. In 1960 and 1961 C. Richard Robins and the late John K. Howard visited Mediterranean countries to obtain specimens, especially from Sicily—the type locality of *T. belone*. Subsequently, Robins and de Sylva (1963) presented data on 35 specimens of *T. belone* from the Mediterranean, redescribed the species, and designated a neotype.

1.21 Affinities

The phylogenetic relations of this species have been reviewed by Robins and de Sylva (1960, 1963). This species clearly has affinities with other small spearfishes and is somewhat closely related to the sailfish genus *Istiophorus*, showing fewer affinities to the genus *Makaira* (*sensu stricto*). It is most closely related to the shortbill spearfish, *Tetrapturus angustirostris* Tanaka, of the Indo-Pacific and is more distantly related to the longbill spearfish, *T. pfluegeri* Robins and de Sylva, of the Atlantic. Its relationships with the roundscale spearfish, *T. georgei* Lowe, are discussed by Robins (1974a). Within the genus, its most distant relatives are the white marlin, *T. albidus* Poey, and the striped marlin, *T. audax* (Philippi).

The genus *Tetrapturus* is briefly characterized by having: the anterior lobe of the spinous dorsal fin higher than the body depth at the dorsal-fin origin, with the lobe often rounded; 12 precaudal plus 12 caudal vertebrae; flesh red; and the size usually small, usually less than 300 pounds (136.1 kg).

A synonymy of *Tetrapturus* was given by Robins

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and de Sylva (1963:385). Because Robins (1974b) repeats this synonymy for *Tetrapturus pfluegeri*, it is not duplicated here.

Artificial key to species of the adult stages (over 10 pounds or 4.5 kg) of *Tetrapturus*

A. Scales along sides of body between pectoral fin and anal fin flexible, broadly rounded anteriorly, with 2 or 3 flattened, soft projections posteriorly . . . . . roundscale spearfish, *Tetrapturus georgei* Lowe

A. Scales along body between pectoral fin and anal fin stiff, decidedly lanceolate, pointed anteriorly, with flattened, hard projections posteriorly . . . . . B

B. Spinous dorsal fin high throughout, the posterior rays about equal in height to the anterior lobe; anus anterior to anal-fin origin by a distance equal to or greater than the anal-fin height; dorsal profile, from dorsal-fin region to near tip of bill, straight; dorsal fin unspotted, body bands absent or faint; premandibular portion of bill shorter than distance from tip of mandible to eye C

B. Spinous dorsal fin low posteriorly, except in small juveniles (less than 10 pounds or 4.5 kg); anus closer to anal-fin origin, distance between them decidedly less than anal-fin height; dorsal profile strongly arched over and behind eyes except in very small juveniles; dorsal fin spotted, the spots usually fading after death but usually apparent in dorsal groove; body bands prominent; premandibular portion of bill longer than distance from tip of mandible to eye . . . . . D

C. Dorsal spines 39 to 46; Mediterranean Sea . . . . . .Mediterranean spearfish, *Tetrapturus belone* Rafinesque

C. Dorsal spines 45 to 53; Atlantic or Indo-Pacific . . . . . E

D. Tips of spinous dorsal, anal, and pectoral fins strongly rounded; height of first dorsal fin less than depth of body at first dorsal-fin origin: Atlantic . . . . . white marlin, *Tetrapturus albidus* Poey

D. Tips of spinous dorsal, anal, and pectoral fins pointed; height of first dorsal fin equal to depth of body at first dorsal-fin origin; Indo-Pacific . . . . . striped marlin, *Tetrapturus audax* (Philippi)

E. Bill short, only slightly exceeding length of lower jaw, premandibular portion of bill contained three times or more in preorbital distance; pectoral fin short, decidedly shorter than pelvic fin length; Indo-Pacific .shortbill spearfish, *Tetrapturus angustirostris* Tanaka

E. Bill long, decidedly longer than lower jaw, premandibular portion of bill contained less than three times in preorbital distance; pectoral fin long in adults, almost equal to pelvic fin in length; Atlantic . .longbill spearfish, *Tetrapturus pfluegeri* Robins and de Sylva

Tetrapturus belone Rafinesque

Type specimen: It is not known if a type specimen was so designated in the generalized account given by Rafinesque (1810:54-55, pl. 1, Fig. 1), or indeed if it was ever preserved.

Neotype: USNM 196527, a male, body length 1,268 mm, collected 2 August 1961 (Robins and de Sylva, 1963:93, Fig. 4, p. 93).

Type locality: Sicily, 200 m off the coast of Punta S. Ranieri, Strait of Messina.

Diagnosis: The diagnosis of *T. belone* is that given by Robins and de Sylva (1963:90-92) as follows:

> First dorsal elements 39-46 (usually 41-46), second dorsal elements 5-7 (usually 6), first anal elements 11-15 (usually 12-14), second anal elements 6 or 7, pectoral rays 16-20 (usually 17 or 18); second anal elements usually equal to or one more than second dorsal elements. Vertebrae 24 (12 precaudal, 12 caudal). Anus far anterior to anal-fin origin, distance 7.8-11 per cent body length (tip of lower jaw to fork of tail), the distance equal to or exceeding height of first anal fin. First dorsal fin unspotted and with high profile, especially in juveniles, its 25th element varying from 13 per cent of body length (at 1268 mm) to 5 or 6 per cent at 1700 mm or longer. Pectoral fin small (10-13 per cent body length throughout range studied). Dorsal profile straight from first dorsal-fin origin to in front of eyes. Bill short, the distance from tip of upper jaw to anterior margin of eye 20-15 per cent of body length (the lower figures characterizing the larger specimens so that the growth of bill shows negative allometry).

The description of *T. belone*, based on 35 specimens, is from Robins and de Sylva (1963:92-95) as follows:

> . . . All [specimens] had 12 caudal and 12 precaudal vertebrae. As the total number of 24 is not known to vary in the Istiophoridae, only caudal vertebrae were counted on 27 specimens; all had 12.
>
> The general body form of *T. belone* changes with growth. Specimens of moderate size (Fig. 4 [upper]; Robins and de Sylva, 1961 [1960]: Fig. 3a) are not unlike *pfluegeri*, although *belone* is heavier (Table 6). As they become larger they become more robust forward (Fig. 5) and in this respect resemble *angustirostris*. The dorsal profile from the origin of the spinous dorsal fin to the base of the bill is straight (Fig. 1 a-c), a feature enhanced by the usual slope of the partly folded dorsal fin. *T. belone* does not have a dorsal hump as in *T. albidus* (see Robins and de Sylva, 1961 [1960]: Fig. 3c). The dorsal and anal profiles are subparallel except in the larger specimens, which are deeper anteriorly. Both *T. belone* and *T. pfluegeri* are flat- or slab-sided but *belone* is thicker (in width) (see graph, Fig. 3) and proportionately deep posteriorly (Fig. 4).
>
> The dorsal fin is lower throughout than in *T. pfluegeri* though the form is much the same. Its anterior height varies from 13-15 per cent of body length (at 766 to 1500 mm body length), gradually decreasing to 12-13 from 1500-1900 mm. This is a gradual trend with considerable variation. The 25th spine is correspondingly reduced and as the posterior spines do not con-

tinue to grow the reduction in percentage of body length is great, from 16 per cent (at 766 mm body length) to 5.1 per cent (at 1868 mm body length). The corresponding proportional reduction, though slight, in anterior height of the spinous dorsal, coupled with increasing depth at the origin of the spinous dorsal, means that in the 1000- to 1500-mm range the fin is higher than the corresponding depth, whereas the reverse is true in the larger specimens.

To show the overall height of the spinous dorsal fin, additional measurements were made in two instances. Med-22: spine 14 (97 mm), 20 (107), 25 (122), 30 (108), 35 (102). Med-26: spine 10 (99), 16 (107), 20 (122), 25 (117, slightly broken), 30 (26), 35 (81).

The first anal fin is low, its anterior height less than the distance from its base to the anus (in one specimen the two distances are equal). Proportionally, the first anal fin varies from 7.2 to 9.3 per cent of body length with no allometry in the size series studied.

A characteristic feature of *T. belone* is its short pectoral fin. It varies somewhat in length and in shape (see Figs. 4-5) but is always quite short (10-13 per cent of body length) and has the upper (or anterior) edge curved, the lower (or posterior) edge nearly straight. The arch of the lateral line ends between the mid-point and the tip of the pectoral fin.

The body is not banded (if bands are present they must not be prominent), but fresh material was not seen by the authors. Body color varied from dark slate above to dull whitish or grey below. The dorsal fin was unspotted in all specimens. While it may be argued that spots may fade, we always found spots in that portion of the dorsal fin below the edge of the groove in the dorsum in each species as white marlin and sailfish, even in very poorly treated specimens. Also, Col. Howard saw some specimens within a few hours of their capture, and noted that none had bands on the body or spots on the spinous dorsal fin. An unspotted dorsal characterizes *T. belone* as it does *pfluegeri* and probably *angustirostris*.

The flesh is pale in *belone* except for the tissue under the lateral line. The importance of this feature in istiophorid taxonomy is uncertain for it may reflect nothing more than feeding habits.

The gas bladder was examined in most specimens and its chambers were arranged in two rows, one layer deep, extending back to the level of the second anal fin. The species has a large pineal window nearly the size of a half dollar.

One juvenile (UMML 11056, Med-36) 766 mm in body length is available to us. Morphometric data are not included in Figure 3 but are available in the tables. At this size it has the characteristic features of the larger specimens.

Material examined:

Spec. Med-2: 1,340 mm body length, weight 25.1 pounds (11.4 kg), male. Zona Scaletta, south of Messina, Aug. 7, 1961 (pectoral girdle, UMML 11074).

Spec. Med-3: 1,290 mm, 26.4 pounds (12.0 kg), male, Torre Faro, Aug.-Sept. 1961.

Spec. Med-4: 1,545 mm, 40.7 pounds (18.5 kg), male, off Sicily, Aug.-Sept. 1961.

Spec. Med-5: 1,670 mm, 50.6 pounds (23.0 kg), male, Strait of Messina, Aug. 7, 1961.

Spec. Med-6: 1,730 mm, 51.7 pounds (23.5 kg), male, Strait of Messina, Aug.-Sept. 1961.

Spec. Med-7: 1,680 mm, 59.4 pounds (26.9 kg), male, Strait of Messina, Aug.-Sept. 1961.

Spec. Med-8: 1,430 mm, 24.2 pounds (11.0 kg), male, off coast of Messina, south side, Aug. 8, 1961.

Spec. Med-9: 1,500 mm, 29.5 pounds (13.4 kg), male(?), Scaletta, Aug. 1961.

Spec. Med-10: 1,522 mm, 28.5 pounds (12.9 kg), male, Tropea, Aug. 9, 1961.

Spec. Med-11: 1,715 mm, 46.2 pounds (21.0 kg), sex unknown, Strait of Messina, Aug. 7, 1961 (piece of skin, UMML 11075).

Spec. Med-12: 1,745 mm, 57.2 pounds (26.0 kg), male, coast of Calabria, region of Calabria, Aug. 7, 1961.

Spec. Med-13: 1,855 mm, 60.5 pounds (27.4 kg), female, Strait of Messina, Aug. 17, 1961.

Spec. Med-14: 1,565 mm, 41.8 pounds (19.0 kg), male, Scaletta, southern section of Straits of Messina.

Spec. Med-15: 1,450 mm, 34.1 pounds (15.5 kg), male, Strait of Messina, Aug. 10, 1961.

Spec. Med-16: 1,345 mm, 23.5 pounds (10.7 kg), male, Strait of Messina, Aug. 1961.

Spec. Med-17: 1,265 mm, 17.6 pounds (8.0 kg), male, Strait of Messina, Aug. 3, 1961.

Spec. Med-18: 1,350 mm, 24.2 pounds (11.0 kg), male, Sicily, Aug. 1961.

Spec. Med-19: 1,435 mm, 26.4 pounds (12.0 kg), sex unknown, Straits of Taormina, Aug. 7, 1961.

Spec. Med-20: 1,510 mm, 30.4 pounds (13.8 kg), female, Strait of Messina, Aug. 4, 1961.

Spec. Med-21: 1,465 mm, 32.8 pounds (14.9 kg), female(?), coast of Messina, Aug. 8, 1961 (pectoral girdle UMML 11073).

Spec. Med-22: 1,455 mm, 30.8 pounds (14.0 kg), male, Zona Scaletta, south of Messina, Aug. 8, 1961.

Spec. Med-23: 1,370 mm, 21.3 pounds (9.7 kg) (gutted), sex unknown, coast of Calabria.

Spec. Med-24: 1,410 mm, 23.1 pounds (10.5 kg), female, Strait of Messina, Aug. 3, 1961.

Spec. Med-25: 1,375 mm, 24.2 pounds (11.0 kg), female, Strait of Messina, Aug. 7, 1961.

Spec. Med-26: 1,460 mm, 29.7 pounds (13.5 kg), female, Strait of Messina, Aug. 3, 1961.

Spec. Med-27: 1,326 mm, 22 pounds (10.0 kg), female, Strait of Messina, Aug. 2-3, 1961.

Spec. Med-28: 1,307 mm, 20.9 pounds (9.5 kg), female, Strait of Messina, Aug. 1961.

Spec. Med-29: 1,390 mm, 26 pounds (11.8 kg), male, Strait of Messina, Aug. 2-3, 1961.

Spec. Med-30: 1,382 mm, 22 pounds (10.0 kg), male, Torre Faro, Aug.-Sept. 1961.

Spec. Med-31: Mutilated, 20.5 pounds (9.3 kg), male, Contesse, 500 m off coast, Aug.-Sept. 1961.

Spec. Med-32: 1,493 mm, 50.6 pounds (23.0 kg), sex unknown, Strait of Messina, Aug. 4, 1961.

Spec. Med-33: 1,640 mm, 44.4 pounds (20.1 kg), female, Strait of Messina, Aug. 4, 1961 (pectoral girdle UMML 11071).

Spec. Med-34: 1,360 mm, 26.4 pounds (12.0 kg), male, Strait of Messina, Aug.-Sept. 1961.

Spec. Med-35: 1,868 mm, 81.4 pounds (36.9 kg), sex unknown, Sicily, Aug.-Sept. 1961.

Spec. Med-36: UMML 11056, 766 mm, juvenile, vicinity of Malta, between Oct. 1 and 13, 1961, Joe Barbara.

In addition, Walter A. Starck, II, has measured and photographed three mounted specimens at the Museo Civico de Storia Naturale di Genova in September 1960, through the courtesy of Enrico Tortonese. All represent *T. belone*, however, and were so identified by Tortonese (1940:175).

Museo Civico Storia Naturale, 18388, 1,773 mm, Laigueglia, West Riviera, Bay of Genoa, Italy, May 18, 1924.

Museo Civico Storia Naturale, uncat., 1,522 mm, no data.

Museo Civico Storia Naturale, uncat., 1,605 mm, no data.

1.22 Taxonomic status

This species is clearly distinguishable from all other species of *Tetrapturus* in the juvenile and adult stage, based upon the research of Robins and de Sylva (1963). Meristic and morphometric data given in that paper clearly permit separation from all other species. *Tetrapturus georgei* Lowe is discussed by Robins (1974a), and is separable from *T. belone* based on characters discussed by Robins.

1.23 Subspecies

No subspecies are recognized.

1.24 Standard common names and vernacular names

In English-speaking countries this species is frequently referred to as the Mediterranean spearfish (Robins and de Sylva, 1963:89). In Italy and Monaco it is known as aguglia imperiale, as aguglia pelerana in Sicily, pastardella in Malta, iglan and iglokljun in Yugoslavia, auggia imbriale in Algeria, bu mkhiat in Morocco, and marlín in Spain. The Japanese have given the common name chichukai-furai, which they distinguish from all other istiophorids. Bini (1968:60, 62) gives regional variation of Italian spelling and pronunciation as the following: agugghia 'mpiriali (Messina and Catania, Sicily); aguggha imperiale, ugghia 'mpiriali (Reggio de Calabria and Crotone); uguglia imperiali (Manfredonia); auglia 'mperiale (Naples); acura 'mperiale (Gallipoli).

1.3 Morphology

The external morphology of the species is described by Rafinesque (1810) and Robins and de Sylva (1963:92-95), and given earlier in the present paper under Diagnosis. Valenciennes (1831:280-286, pls. 227-228) supplied detailed information on the gross morphology and skeletal structure. Characterization of the larval and juvenile stages is discussed herein under the sections on "Reproduction" (3.1).

2 DISTRIBUTION

2.1 Total Area

The Mediterranean spearfish, *T. belone,* is known only from the Mediterranean Sea including the Ligurian, Adriatic, and Ionian seas (Robins and de Sylva, 1963:96-97). It is the most common istiophorid in the central basin around Italy.

Tetrapturus belone is recorded with reasonable certainty from Sicily (Rafinesque, 1810:54-55, Fig. 1), Messina (Cocco, 1884:373; Spartà, 1953, 1961, Cavaliere, 1962), the Gulf of Naples (Padoa, 1956: 513-516), Palermo (Gigliogli, 1880), Taranto (Costa, 1850:10; Canestrini, 1872:12), Venice (Ninni, 1912:271), the Ligurian Sea (Parona, 1898:368; Tortonese and Trotti, 1949:134), Malta (Gulia, 1861, 1871), Mallorca (Barceló y Combis, 1868:388), the Adriatic (Trois, 1880: 643-645), and Split, Yugoslavia (Kolombatvić, 1886; Šoljan, 1948:376, 389).

Although Robins and de Sylva (1963:96) indicated that it has not been taken from the eastern Mediterranean, Ben-Tuvia (1953) reported upon a juvenile billfish (356 mm) from off Haifa, Israel, which he identified as *Istiophorus gladius* (Broussonnett). The present writer subsequently examined the specimen and identified it as the young of *T. belone*, which was later reported by Ben-Tuvia (1966:271-272). A second juvenile specimen (597 mm SL) was collected by the Woods Hole Oceanographic Institution's vessel RV *Chain* on 2 October 1966. This specimen (de Sylva and Ueyanagi)[3] was taken by night light and dip net off Lebanon, lat. 34°20.5′N, long. 34°41.0′E, and was one of two reported seen under the light (F. J. Mather III, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, Miami, FL 33149, pers. commun.) However, no adults have been reported east of the Ionian Sea. Because of the difficulty in identification of juvenile and adult billfish, it is possible that the species is more widely distributed in the Mediterranean than has been reported in the literature and that spearfish may have been identified by sport and commercial fishermen as white marlin, *Tetrapturus albidus* Poey, which occur in the western and central Mediterranean (Rodríguez-Roda and Howard, 1962; de Sylva, 1973).

References to *T. belone* outside of the Mediterranean Sea cannot be verified (Robins and de Sylva, 1963:96-97) and are probably based upon *T. albidus* Poey or *T. georgei* Lowe. For a discussion of the latter,

[3]de Sylva, D. P., and S. Ueyanagi. Systematics, development, and distribution of the Atlantic species of the family Istiophoridae. Manuscript in preparation. Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL 33149.

poorly known species, see Robins (1974b). Nakamura, Iwai, and Matsubara (1968) refer to spearfish being taken "from the northeast and north-central Atlantic." However, their illustrations (Fig. 18) do not appear to be of *T. belone* or of *T. pfluegeri*; they may represent *T. georgei* or even an undescribed species.

Tetrapturus belone belongs ecologically to the ichthyofauna of the oceanic epipelagic (Parin, 1968). It evidently completes its entire life history in the open sea. However, because of the steepness of the continental shelf and the proximity to shore of oceanic waters in the Mediterranean, this spearfish could come very close to land.

Vertical distribution is unknown. It is usually taken at the surface by harpoon and several types of nets. In the Gulf of Castellammare (Sicily) and near the towns of Torretta Granitola and Marinella, a few are caught in tuna traps (Robins and de Sylva, 1963:96). It is occasionally caught by using flag lines and drifted handlines. Like other billfish, it probably feeds in the upper 200 m (epipelagic), generally above and within the thermocline.

2.2 Differential Distribution

2.21 Spawn, larvae, and juveniles

Spawning areas are unknown. Lo Bianco (1903, 1909), Spartà (1953, 1961), Padoa (1956), and Cavaliere (1962) reported larval stages of *T. belone* from the Strait of Messina.

The larvae reported by Lo Bianco (1903, 1909) cannot be identified with certainty, in spite of the statement by Robins and de Sylva (1963:95-96), which notes that one larva (illustrated by Padoa, 1956:514-516, pl. 36, fig. 7) "is clearly an istiophorid and, . . . probably . . . *T. belone*." It seems probable that the larvae depicted by Spartà (1961) may well be those of *T. belone* because the adults of other istiophorids are not common near the Strait of Messina.

As mentioned earlier, two juveniles (356 mm and 597 mm) were taken from Haifa, Israel, and off Lebanon, respectively. These represent the only two early juvenile specimens of *T. belone* which can definitely be identified. Rafinesque's (1810) type specimen, a juvenile, was from Sicily but this does not indicate that the specimen was spawned nearby. A juvenile of 37 mm was taken in the Strait of Messina along the beach at Ganzirri (Cavaliere, 1962:Fig. 2), which agrees with the 597-mm specimen collected from Lebanon except for the lower dorsal fin and the lack of spots on the anterior rays. A juvenile billfish (BMNH) from Malta is figured by de Sylva and Ueyanagi (see footnote 3); however, is it unlikely that this is the young of *T. belone* because of the peculiar, extensive markings on the dorsal fin, which are limited to a few spots on the anterior rays in the larger juveniles of *T. belone* from Israel and Lebanon. Thus, nursery grounds for juveniles of *T. belone* are known only from the eastern Mediterranean Sea.

2.22 Distribution of adults

Adults of *T. belone* are most common in the central Mediterranean about the Strait of Messina. Such inferences are based solely upon the catch of commercial fishermen, usually using harpoons, who are concentrated in this area. However, commercial fishing using the same method occurs throughout the Mediterranean for broadbill swordfish, *Xiphias gladius* Linnaeus, and it could be expected that *T. belone* would be collected elsewhere if it were common. There are no data on seasonal and annual variations in abundance or availability. Spartà (1961) noted that spearfish occurred in the Strait of Messina in August and September, and were rare in October and November, with some examples being taken during the winter. He noted that they preferred the upper waters of the Strait of Messina, which may well be associated with upwelling and the consequent concentration of food in these upper waters.

2.3 Determinants of Distribution Changes

As an inhabitant of the oceanic epipelagic, *T. belone* is a stenotopic species whose habitat at all stages of its life history is characterized by narrow geographical and seasonal variation in temperature, salinity, and other physicochemical parameters. Like other billfishes, it is typically a clear-water species requiring high-transparency waters for its feeding (which is largely visual. Robins and de Sylva (1963:97-98) postulated that the hypersaline waters and associated changes in temperature and dissolved oxygen of the eastern Mediterranean, especially the Levantine Basin, probably were influential in excluding *T. belone* from the eastern Mediterranean. This may be true for adults, although it does not apply to juveniles inasmuch as three are now reported herein from Israel and Lebanon.

Its food habits are poorly known. Probably it feeds upon clupeoids and sauries, whose distribution is closely determined by oceanographic conditions. Thus, changes, either natural or man-made, should be expected to affect the distribution of *T. belone*. Organisms concentrated at or just above the thermocline (de Sylva, 1962; de Sylva and Davis, 1963) should be expected to concentrate *T. belone* for feeding purposes (Hela and Laevastu, 1970).

Presumably, drastic changes in the habitat, such as from local freshwater runoff or pollutants, would affect the distribution of this stenotopic species at all stages of its life history.

2.4 Hybridization

No natural hybrids of this species are known. Popular speculation contends that all billfish hybridize, but there is no scientific evidence to substantiate this.

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

As far as known, all billfishes, including *T. belone*, are dioecious. Fat deposits adhering to the ovaries of billfishes during their vegetative period are frequently mistaken for testes by fishermen, and hence it is popularly believed that some billfishes are hermaphroditic.

Sexual dimorphism is marked in the related istiophorid genus *Makaira* (*sensu stricto*), with the females growing to a much larger size (de Sylva, 1963a). Nakamura (1949) noted that the Pacific *T. angustirostris* did not exhibit sexual dimorphism, there being no difference in the mean weight of males and females.

Robins and de Sylva (1963:96) found that their data on the mean weight of males and females of *T. belone* were inadequate. No difference in mean size of the sexes was found in the related *T. albidus*, according to de Sylva and Davis (1963). There is no evidence that there are sexual differences in color or morphometric characteristics in *T. belone*.

3.12 Maturity

Nothing is known regarding the size or weight at which sexual maturity is reached in *T. belone*.

3.13 Mating

The spawning act has not been observed, nor is anything known about the location of spawning. Rafinesque (1810) commented that the fish usually travel in pairs, a male and a female together, and that very often both are captured together.

3.14 Fertilization

Reproductive behavior or fecundity have not been studied. Undoubtedly, fertilization is external. Spartà (1953, 1961) has described the pelagic eggs, from the plankton, of *T. belone*.

3.15 Gonads

Robins and de Sylva (1963:96) noted that the sex of 27 specimens of *T. belone* was difficult to determine. This may be because they were examined in August, which should represent a refractory period when the gonads are not well developed, if the hypothesis of Spartà (1953) is correct that spawning occurs from spring to summer. That Spartà (1961) found eggs in the plankton in May would further suggest that spawning is long complete by August.

The gonads of 27 fish examined from Sicily were asymmetrical, λ-shaped (the left side longer in one female, the right side longer in most others), and very orange (Robins and de Sylva, 1963:96).

3.16 Spawning

Spartà (1953) reported on eggs and larvae from the Strait of Messina. He identified eggs from plankton taken in May. The identity of the larvae, 4.88 and 5.24 mm, is questionable (Gehringer, 1956:169; Ueyanagi, 1962:186; Robins and de Sylva, 1963:95). Subsequently, Spartà (1961) indicated the spawning period as spring to summer. The difficulty encountered in identifying the sex of gonads from 27 specimens of *T. belone* collected in August from Sicily suggests that spawning did not occur during this period. The occurrence of juveniles in October (Spartà, 1961:20) also suggests a late-spring spawning period. However, an earlier spawning season (i.e., winter months) cannot be precluded. A spawning season of December through February is postulated for *T. pfluegeri* in the western Atlantic by de Sylva and Breder,[4] and a winter or spring spawning season might not be an unreasonable hypothesis for *T. belone*. Ueyanagi, 1962:188; Ueyanagi (in Howard and Ueyanagi, 1965:103) concluded that *T. angustirostris* spawned more intensively in winter in the Pacific.

Spawning has not been observed, but larval stages of *T. pfluegeri* have been reported from far offshore (de Sylva and Ueyanagi (see footnote 3)). Other istiophorids (excluding the neritic *Istiophorus*) appear to spawn far from shoal water, and it is likely that *T. belone* similarly spawns offshore.

3.2 Pre-Adult Phase

3.21 Embryonic phase

The pelagic eggs of *T. belone* collected from the plankton are described in detail by Spartà (1953, 1961). The eggs averaged 1.48 mm in diameter and the oil globule was yellow-green. The eggs were incubated for several days and their development is described in detail.

3.22 Larval phase

Two larval specimens of *T. belone* collected near Capri, off Punta Campanella, were described by Lo Bianco (1903:127, 166, 238). Comparisons of these specimens with other istiophorid larvae were made by Lo Bianco (1909:755). Larvae from Messina reported by Spartà (1953) do not seem to be those of istiophorids (Gehringer, 1956:169; Ueyanagi, 1962:186; Robins and de Sylva, 1963:95-96). Larger specimens (29 and 54 mm) were reported from the coast of Faro, Strait of Messina, apparently thrown ashore from the southeast wind (Sirocco). These two

[4]de Sylva, D. P., and P. R. Breder. Gonad histology and reproductive cycle in the Atlantic species of the Istiophoridae. Manuscript in preparation. Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL 33149.

specimens were an extreme rarity, other examples not having been found in the past 50 yr in spite of diligent research (Spartà, 1961).

3.23 Adolescent phase

A juvenile specimen of *T. belone* (356 mm) was reported (as *Istiophorus gladius* (Broussonet) by Ben-Tuvia (1953:18), which was subsequently reidentified (Ben-Tuvia, 1966) as *T. belone*. A second specimen (597 mm) was collected by the Woods Hole Oceanographic Institution's RV *Chain* off Lebanon. The striking characteristic of these specimens is that they generally resemble the adult except that the first dorsal fin is high and saillike, almost as in the genus *Istiophorus* (see de Sylva, 1963b:Fig. 2). A high dorsal fin in the adolescent phase is common to all istiophorids, and accounts for much misidentification of young stages in the literature.

The dorsal fin is unlike that of the young of *Istiophorus* in that it lacks diffuse blotches (see Gehringer, 1956, 1971; de Sylva, 1963b:Fig. 3). *Istiophorus* has not been reported from the Mediterranean, nor has the blue marlin, *Makaira nigricans* Lacépède, but both could occur there and should be looked for (de Sylva, 1973). The dorsal fin of the young of *Makaira* is distinctively convex, reaching its highest point anteriorly. It has a distinct wavy pattern not seen in other istiophorids. Young of *Tetrapturus albidus* are known from North Carolina (de Sylva, 1963b: Fig. 1) and off Havana (Anonymous, 1968). They have five or six distinctive dark ocelli rimmed with pale areas, near the base of the first dorsal fin. The young of *T. belone* is unique in that the dorsal fin bears several small, dark blotches at the bases of the anterior rays, and at the tips of the first few rays, the rest of the fin being dusky and otherwise unmarked.

Other features of development between the adolescent and adult stages are less distinctive. The body of the adolescent is typically thin and slab-sided, which increases in robustness in the adult. The bill, long and slender in the adolescent, is negatively allometric, being relatively short in the adult. Characteristic of all the spearfishes is the shape of the first dorsal fin in the adult, which has a slight lobe anteriorly, sloping abruptly behind the first several rays, then running long and high, paralleling the dorsal profile (see Robins and de Sylva, 1960:406; 1963:93, Fig. 4).

3.3 Adult Phase

3.31 Longevity

Nothing is known of the rate of growth or maximum age of *T. belone*. Size-frequency analysis of adults, used by de Sylva (1957) to estimate age and growth of *Istiophorus americanus*, requires a great deal of size data from individual specimens, which are presently unavailable.

3.32 Competitors

Tetrapturus belone is ecologically quite similar to the broadbill swordfish and *T. albidus*, with which it undoubtedly competes for food. The blue shark, *Prionace glauca*, and the bluefin tuna, *Thunnus thynnus*, are other large predators which occur in the same ecological niche and which probably feed upon the same organisms. The broadbill swordfish and the bluefin tuna are routinely caught by commercial fishermen about Sicily using the same harpoon and trap-net techniques by which *T. belone* is taken.

3.33 Predators

Because of the relatively large size attained by *T. belone*, it is probably not preyed upon extensively in the adult phase except by sharks. The blue shark is occasionally common off Sicily and probably could be considered as an important predator, though the blue shark, being somewhat sluggish, would probably be more successful in capturing species not as swift as *T. belone*.

3.34 Parasites, diseases, injuries, and abnormalities

Nothing has been published on parasites and diseases of *T. belone*. A parasitic copepod (*Penella*), common on all istiophorids, has not been reported for *T. belone*. Abnormalities, such as deformed dorsal fins, broken or bent bills, and broken pectoral or caudal rays, are common among other istiophorids, but no such deformities are reported for *T. belone*.

3.4 Nutrition and Growth

3.41 Feeding

Feeding habits of *T. belone* have not been reported in the literature. Based on their food habits, however, they probably are visual feeders of the upper, well-lit layers. It is not known if they feed at night. Antonio Spartà reports (in Robins and de Sylva, 1963) that *T. belone* follows schools of Atlantic sauries, *Scomberesox saurus*, into the Strait of Messina and, hence, in this region they are feeders in the shallower strata of the epipelagic zone. Spartà (1961:20) wrote that *T. belone* preferred the upper waters of the Strait of Messina.

Probably because there is considerable upwelling of food and nutrients into the upper layers of the Strait of Messina, *T. belone* finds an ample food supply in the upper waters so that it does not have to search the deeper strata for food, such as occurs with many other istiophorids. About Messina, fishermen harpoon them during their fishing period from early in the morning (0530-0600) until about 1600. Since night fishing is not carried out here, therefore, specimens have not been studied to disclose if they feed at night. Cavaliere (1962:172) reported that, to the south of the

Strait of Messina, *T. belone* is caught at night with "palamidara," vertical nets used to catch albacore, *Thunnus alalunga*. Possibly *T. belone* is feeding at this time, although no reports on feeding or food habits based on night-caught specimens are forthcoming.

3.42 Food

The food of *T. belone* was discussed by Robins and de Sylva (1963:95), based on specimens caught by fishermen. Since specimens reported on from Sicily were not fresh, and many had been ultimately frozen, thawed, and refrozen, most contained only unrecognizable remains. Many had fish skeletons, which were evidently of Atlantic sauries and sardinelike vertebrae. A few contained the needlefish *Belone belone*. Rafinesque (1810) reported that in autumn off the Sicilian coast, *T. belone* pursues dolphins; pilotfish, *Naucrates*; and flyingfishes.

3.5 Behavior

3.51 Migrations and local movements

Seasonal movements of *T. belone* are based entirely upon their capture by commercial fishermen. Distinct migrations are not documented, nor is it known whether the appearances of *T. belone* in the commercial fishery results in longitudinal or vertical movements to the surface fishery where they can be captured by harpoons and shallow nets.

Adults occur in the Strait of Messina, the area of heavy fishing, in August and September, and occasionally in October and November. Some examples are rarely captured in winter (Spartà, 1953, 1961; Cavaliere, 1962; Bini, 1968).

3.52 Schooling

No mention is made in the literature as to the schooling of *T. belone*, but it seems unlikely because other istiophorids do not school in the strict sense. Rafinesque (1810) and Valenciennes (1831) reported that *T. belone* frequently travels in pairs, this being known to occur in other istiophorids, possibly being a behavioral mechanism for feeding.

4 POPULATION

4.1 Structure

Nothing is known of the sex ratio or age composition of the populations of *T. belone*. Robins and de Sylva (1963:96) reported that of 27 specimens taken off Sicily by commercial fishermen, 19 were males and 8 females.

The usual size composition of the commercial catch of *T. belone* is from 10 to 30 kg (Cavaliere, 1962:172), averaging about 2 m long (Spartà, 1961:20). Specimens of 4 to 5 kg are rarely caught. Maximum size reported is about 70 kg (Rafinesque, 1810).

5 EXPLOITATION

5.1 Fishing Equipment

The fishery for *T. belone* occurs incidentally to that carried out for the swordfish (Spartà, 1961; Cavaliere, 1962:174). In the Strait of Messina, the major gear is the harpoon (fiocini), although *T. belone* is occasionally captured in nets (ravastina) which are used for Atlantic sauries, locally called "costardella," on which *T. belone* feeds. To the south *T. belone* is occasionally caught in vertical nets (palamidare) which are used principally for albacore.

5.2 Fishing Areas

5.21 General geographic distribution

See 5.22.

5.22 Geographic ranges

The fishing area in the Strait of Messina (both Sicilian and Calabrian coasts) occurs from Bagnara-Capo Rasocolmo in the north in the Tyrrhenian Sea, and from Capo Giardini-Melito di Porto Salvo to the south in the Ionian Sea. In addition to the harpoon fishery, a few specimens of *T. belone* are caught in traps set for tuna in the Gulf of Castellammare and near the towns of Torretta Granitola and Marinella. Little is known specifically about the fishing grounds in the remainder of the Mediterranean Sea, and no quantitative data are available on the annual or seasonal catch in various counties.

Francesca R. LaMonte kindly sent me an English translation of a paper by Mazzullo (1906) which documents the swordfish fishery in the Strait of Messina; because this fishery also captures *T. belone*, the techniques and gear used in the fishery are noteworthy. Mazzullo gives a general summary of the composition of manpower in a typical fishing operation for swordfish off Sicily, including the number and kinds of personnel involved per vessel and the eventual distribution of fish and profits.

6 PROTECTION AND MANAGEMENT

6.1 Regulatory (Legislative) Measures

No data.

6.2 Control or Alteration of Physical Features of the Environment

See 6.3.

6.3 Control or Alteration of Chemical Features of the Environment

The relationship between the community population structure, though presently unknown, and the ecosystem will ultimately depend on man's effects upon the high-seas environment in which *T. belone* lives. Hypersaline conditions resulting from the reduced freshwater flow of the Nile River are increasing in the eastern Mediterranean, from which two juveniles of *T. belone* are reported, so that, if this were to constitute an important nursery ground for the juveniles, high salinity water would be expected to be unfavorable to this stenotypic species.

Man-made pollution, especially from oil and other petrochemicals, sewage pollution, and radioactivity, is potentially detrimental via the food chain, even to an epipelagic species such as *T. belone*. For example, Horn, Teal, and Backus (1970) found lumps of crude oil residue to be widely dispersed in the Mediterranean Sea and the eastern North Atlantic Ocean, stressing that toxic fractions of hydrocarbons have been isolated from these lumps. They found large amounts of tar in the stomachs of Atlantic sauries collected southwest of Sardinia, and concluded that "this ingestion of the tar by sauries provides a direct introduction of a material known to be toxic into the oceanic food web." Because *T. belone* feeds mainly upon sauries, there is a possibility that an important part of the food web of *T. belone* could be affected if sauries are eventually killed by the toxic hydrocarbons. Further, concentrations of toxic hydrocarbons which were sublethal to the sauries could be theoretically concentrated within their bodies and eventually in *T. belone* and persons feeding upon them. Other man-made components, especially the chlorinated hydrocarbons, should be expected to occur in the tissues of *T. belone*, and could conveivably affect spawning or other metabolic processes, in addition to becoming concentrated in various tissues eaten by man.

6.4 Control or Alteration of the Biological Features of the Environment

See 6.3.

7 POND FISH CULTURE

Not applicable.

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Synopsis of Biological Data on Striped Marlin, *Tetrapturus audax* (Philippi), 1887

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1 IDENTITY

1.1 Nomenclature

1.11 Valid Name

Tetrapturus audax (Philippi), 1887 is the name adopted by the most recent review of the family (Nakamura, Iwai, and Matsubara, 1968). The original combination was *Histiophorus audax* Philippi, 1887. Anal. Univ. Chile 71:34-39.

1.12 Objective synonymy

All synonyms are assumed to be subjective without consulting original papers and are listed under section 1.21.

1.2 Taxonomy

1.21 Affinities

Suprageneric

Phylum Chordata
Subphylum Vertebrata
Superclass Gnathostomata
Class Osteichthyes
Subclass Actinopterygii
Order Perciformes
Suborder Xiphioidei
Family Istiophoridae

Generic

Genus *Tetrapturus* Rafinesque, 1810.

Caratteri di alcuni nuovi generi e nuove specie di animali [principalmente di pesci] e piante della Sicilia, con varie osservazioni sopra i medisimi. Palermo, 105 p.

Type-species *Tetrapturus belone* Rafinesque, 1810.

Robins and de Sylva (1960, 1963) placed the striped marlin in *Tetrapturus*, following the works of hierarchical classification of the family by Hirasaka and Nakamura (1947) and Nakamura (1949). This placement of *audax* in *Tetrapturus* is supported by Ueyanagi (1963b), Howard and Ueyanagi (1965), and Nakamura et al. (1968).

We follow the generic concept of Nakamura et al. (1968), who described the genus as follows:

> The height of the dorsal fin is greater than the body depth. The ventral fin rays are rather long, the fin membrane not well developed. The body is compressed (flat) and except for the striped marlin (Makajiki) and the white marlin (Nishimakajiki), extends in a straight line from the pre-occular area to the base of the dorsal fin. The cranium is long and narrow. The neural and haemal spines of the central vertebrae form a parallelogram. There are 24 vertebrae (12 + 12 = 24). The lateral appophysis[3] is not well developed.

These authors include the following species in the genus: *T. angustirostris* Tanaka, 1914; *T. belone* Rafinesque, 1810; *T. pfluegeri* Robins and de Sylva, 1963; *T. albidus* Poey, 1861; *T. audax* (Philippi, 1887).

Specific

Identity of type specimen:

Species *T. audax* (Philippi, 1887).

Type specimen: Apparently one of the two deposited in the Museo Nacional de Historia Natural, Santiago, Chile by Rudolfo A. Philippi.

Type Locality: Iquique, Chile.

Diagnosis: Ventral fins and two caudal keels are present; snout cross section is nearly circular; first dorsal fin anteriorly is about same height as body depth or greater[4] and is not saillike but slopes abruptly

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[3]See Ueyanagi and Watanabe (1965) for usage of this term.

[4]Due to allometric growth of the dorsal fin relative to body depth the fin height may be less than body depth in fish larger than 360 cm FL (Royce, 1957).

posteriorly, the middle rays being much shorter than the anterior; snout is fairly long; vent is located very close in front of first anal fin; pectoral fins are fairly broad and long and fold against body; and the tips of pectorals, first dorsal, and first anal fins are pointed.

Subjective synonymy:

Histiophorus audax	Philippi, 1887
Istiophorus audax	Delfin, 1901
Tetrapterus mitsukurii	Jordan and Snyder, 1901
Tetrapturus ectenes	Jordan and Evermann, 1926
Makaira audax	Jordan and Evermann, 1926
Makaira grammatica	Jordan and Evermann, 1926
Makaira holei	Jordan and Evermann, 1926
Makaira mitsukurii	Jordan and Evermann, 1926
Makaira zelandica	Jordan and Evermann, 1926
Marlina mitsukurii	Grey, 1928
Marlina zelandica	Whitley, 1937
Kajikia mitsukurii	Hirasaka and Nakamura, 1947
Kajikia formosana	Hiraska and Nakamura, 1947
Tetrapturus tenuirostratus	Deraniyagala, 1951
Tetrapturus acutirostratus	Deraniyagala, 1952
Makaira formosana	Matsubara, 1955
Tetrapturus brevirostris	Munro, 1955
Marlina audax	Smith, 1956a, b
Marlina jauffreti	Smith, 1956b
Tetrapturus audax	Robins and de Sylva, 1960
Makaira jauffreti	Jones and Silas, 1964

Artificial key to genus (Nakamura et al., 1968):

A. Anterior fin rays of first dorsal fin fairly high, posterior rays about same height; vent situated decidedly anterior to origin of the first anal fin; second anal fin anterior to second dorsal fin.

B. Pectoral fin narrow and short

C. Snout very short. . . Shortbill spearfish (Furaikajiki) *T. angustirostris* Tanaka.

CC. Snout fairly long . . . . . Mediterranean spearfish (Chichukaifurai). *T. belone* Rafinesque.

BB. Pectoral fin wide and long . . . . . Longbill spearfish (Kuchinagufurai) *T. pfluegeri* Robins and de Sylva.

AA. Height of anterior portion of first dorsal fin about same as the body depth but gradually decreasing in height posteriorly; vent directly anterior to the origin of the first anal fin; second dorsal fin and second anal fin in parallel positions.

D. Pectoral fin wide and its tip rounded. The tip of the first dorsal fin and first anal fin rounded . . . . . White marlin (Nishimakajiki) *T. albidus* Poey.

DD. Pectoral fin narrow, and its tip pointed; the tips of the first dorsal fin and first anal fin pointed . . . . . Striped marlin (Makajiki) *T. audax* (Philippi).

1.22 Taxonomic status

The species is established on the basis of morphology without breeding data.

The species may be polytypic (see 1.31 below).

1.23 Subspecies

No subspecies are recognized.

1.24 Standard common names and vernacular names

Country	*Standard common name*	*Vernacular name(s)*
Sri Lanka		Seraman Koppara
Chile		Pez aguja
China		Chi zuo fo yii
Japan	Makajiki	Maka, Kajiki, Kajikimaguro, Nairagi, Nairage, Nairanbo
Kenya		Nduaro
Mexico	Marliń rayado	Marliń, agujon, pez puereo
New Zealand	Striped marlin	New Zealand marlin
Philippines		Spearfish
Russia		Polosatii marlin
Taiwan	Hung ju chi yii	Hung ju ting pan
United States	Striped marlin	Pacific striped marlin, barred marlin, Pacific marlin, striped swordfish, spearfish, spikefish
Vietnam		Ca co Mitsukurii

1.3 Morphology

1.31 External morphology (for description of spawn, larvae, and adolescents, see 3.17, 3.22, 3.23).

Generalized: Gregory and Conrad (1939) provide a scale diagram of the striped marlin outline based on modal body proportions of 30 specimens from New Zealand and Australia using standard length as the basic body measurement. Thirty-eight measurements were made on each specimen and are published in absolute and as percentage of standard length along with total body weight.

Nakamura et al. (1968) provide the following description:

External Characters. The first dorsal fin has 37-42 fin rays. The second dorsal fin has 6 soft rays. The first anal fin has 13-18 fin rays. The second anal fin has 5-6 soft rays. The pectoral fin has 18-22 soft rays. The ventral fin has one spine and 2 soft rays. The

body is elongated (the body length is about 5.9-7.3 times the body depth) and is rather thick. The snout is long (the head length is about 0.88-0.99 times the length of the maxillary), and its cross-section is almost round. The body is densely covered with scales; the tips of the scales are pointed. Scales from specimens less than 1 meter in length do not have this species characteristic. There are small file-shaped teeth on both jaws and on the palate. The lateral lines on the sides curve over the pectoral fin and then continue in a straight line to the area of the caudal fin. The head is large (the body length is 3.6-3.8 times the length of the head). The eyes are moderately large. There is a relatively conspicuous crest on the outer edge of the head between the pre-occular region and the origin of the first dorsal fin. There are 2 scutes on each side of the tail near the caudal peduncle; the tail is strong and deeply forked. The pectoral fin, has a pointed tip and is located rather low on the body; it is shorter than the head (the head length is about 1.14-1.99 times the length of the pectoral fin). The first dorsal fin begins above the posterior end of the pre-opercle bone; its first few rays are larger than the body depth, but as it progresses towards the back, it gradually becomes shorter, ending just in front of the origin of the second dorsal fin. The tip of the first anal fin is pointed, large and sickle-shaped. The second dorsal fin and the second anal fin are about the same size and shape. The latter is located a little further forward on the body than the former. In spite of the fact that the ventral fin is longer than the pectoral fin in smaller specimens, the opposite is true for larger specimens. The fin membrane of the first dorsal fin is dark blue. The back of the body is dark blue with splotches of black on it; towards the ventral side of the body, 10 or more rows of cobalt-colored stripes are clearly visible. The other fins are blackish brown, or sometimes a dark blue. The bases of the first and second anal fins are silvery-white.

Morrow (1952a) published morphometric data on 49 specimens from New Zealand and later (Morrow, 1957) published extensive morphometric data and anal ray counts on 39 fish from Peru. These data include standard length as the basic body length measurement. Ueyanagi (1957b) presented morphometric data on young specimens, 80- to 180-cm eye-fork length, from the western North Pacific. Royce (1957) reported extensive morphometric data of 25 specimens from the central Pacific using fork length as the basic measurement but also giving standard length and eye-fork lengths for some specimens. He also published more limited data on 30 specimens measured by the Hawaii Division of Fish and Game. Kamimura and Honma (1958) published morphometric data on five characters using eye-fork length as the basic body measure for 56 fish south of the equator and 124 fish north of the equator in the western Pacific. Williams (1967) presented dorsal and anal fin ray counts of 13 specimens from East Africa. Merrett (1971) gives fin measurements on about 23 other specimens.

Counts have been given by several authors and are shown in Table 1.

Georgraphic variation: Geographic variation appears to be considerable. Morrow (1957) concluded that striped marlin from Peru and northern New Zealand represented separate and distinct populations based on significant differences in 11 morphometric and meristic characters as follows: average absolute lengths of pelvic fins, counts of spines and rays in the first anal fin, and the regressions of the following measurements on standard length: greatest body depth, length of base of second dorsal fin, length of base of first anal fin, width of base of pectoral fin, snout tip to origin of first dorsal fin, snout tip to origin of second dorsal fin, snout tip to origin of first anal fin, snout tip to posterior edge of operculum, snout tip to posterior end of maxillary. By a character index (CI) in which

$$CI = \frac{\text{pelvic length}}{10} - \frac{100}{SL} \text{ (Depth + Length}$$

of anal base + Width of pectoral base), Morrow could separate correctly about 72% of the 69 specimens from which the index was derived. The New Zealand specimens tended to have character indices of considerably lower numerical value than the Peru specimens.

In the western Pacific (west of long. 170°W) Kamimura and Honma (1958) found a remarkable difference in the lengths of the pectoral fins between northern (lat. 30°-35°N) and southern (lat. 18°-25°S) striped marlin. Covariance analysis of regression of pectoral fin on eye-fork length showed no significant difference in slope of regression but a highly significant (0.01) difference in adjusted means. Also significant differences (0.05) were found for both regression coefficients and adjusted means for regressions of eye-to insertion of second dorsal on eye-fork length. From these differences these authors concluded northern and southern populations in the western Pacific were extremely separated. In intermediate waters of the northern hemisphere (lat. 5°-25°N) all but three fish had pectoral lengths clustered about the regression line for the northern population. The pectoral lengths of the other three fish, which were taken from lat. 5° to 15°N, were close to the regression line for the southern population and were presumed to have strayed from that population.

Honma and Kamimura (1958) supported the hypothesis of separate north and south populations in the western Pacific with the following observations:

a) a zone of low hook-rate along the equator separates the populations;
b) the main spawning grounds are widely separated and spawning seasons are a half-year apart;
c) the maximum size attained is much larger in the southern population;
d) adaptations of the two populations to environmental circumstances do not coincide in details, differing with growth stages.

Howard and Ueyanagi (1965) extended the

Table 1.—Fin-ray counts of *Tetrapturus audax*.

Area and author	First dorsal fin	Second dorsal fin	First anal fin	Second anal fin	Pelvic fins	Pectoral fins
Chile						
Philippi, 1887	38	5	12	5	1	
Western Pacific						
Nakamura, 1938, 1949	37-43 (III+12–15+XXII–XXV)	6	14-15 (II+12–13[1])	6	1+2	
Western Pacific						
Ueyanagi, 1959	37-44					
New Zealand						
Morrow, 1957			12-16			
Peru						
Morrow, 1957			14-17			
East Africa						
Williams, 1967	35-41	5-7	11-15	5-6		
Peru						
Morrow (unpubl.) (after Williams, 1967)	37-44	5-7	14-17	5-7		
East Africa						
Morrow (unpubl.) (after Williams, 1967)	36-41	5-7	11-15	5-6		
East Africa						
Merrett, 1971	38-42	5-7	13-16	5-6		19-23
Eastern North Pacific						
Wares and Sakagawa, 1974		5-7		5-7		

[1]The figure of 25 which appears here in the translation of the 1949 paper is evidently a misprint.

hypothesis by including eastern Pacific fish in the southern population and demonstrating that growth of the pectoral fin is allometric with an inflection at about 185-cm eye-fork length. They pointed out that mixing of the two populations occurs in the tropics and suggested that Mexican fish belong principally to the southern-eastern group and that southern California fish are derived from both groups but dominated by the northern.

Merrett (1971) found striped marlin of the tropical western Indian Ocean to have relatively long pectoral fins indicating a closer relation to the southern-eastern population than to the northern.

There has been little mention in the literature of geographical variation in color pattern, but the striking almost zebralike bars on the freshly caught New Zealand specimen in the photo published by Gregory and Conrad (1939) appears more pronounced than in fish from other regions.

To date, the knowledge of subpopulations, if they truly exist, is insufficient for morphological definition.

The morphological changes of larvae and adolescent phases are of course remarkable. See 3.22 and 3.23.

Morrow (1952a) found significant ($P < 0.001$) negative allometry in the dorsal and ventral lobes of the caudal fin and a slight but not statistically significant ($P = 0.065$) negative allometry in the length of the pectoral fin of 49 adult fish from Cape Brett, New Zealand. The pelvic fins show extreme negative allometry appearing to cease growth after reaching a certain size (Morrow, 1957; Royce, 1957). Negative allometry was found in Peruvian specimens for body depth and snout tip to origin of first anal fin (Morrow, 1957). Ueyanagi (1957b) found extreme negative and positive allometry, respectively, in central dorsal rays relative to body depth and pectoral length relative to body depth in young specimens (85-175 cm) which proved the synonymy of *Kajikia formosana* and *T. audax*. Royce (1957) also found similar allometry.

Ontogenetic change in body form is shown in Figure 1. The morphological change of the snout (its growth relative to the body length) from the postlarval to adult stage of striped marlin is relatively small in comparison with those of other istiophorid species. However, the change of the dorsal fin shape during growth is remarkable in this species (Ueyanagi, 1963b).

In relation to functional morphology, Fierstine (1968) found an average aspect ratio (span/surface area of one side of fin) of 9.0 for the caudal fin of three striped marlin from the eastern Pacific. This high ratio, indicating relative efficency as a hydrofoil, was greater than that for seven other scombroid species but less than that for the sailfish, *Istiophorus platypterus*, and the white marlin, *T. albidus* (10.0 and 10.3, respectively).

Published weight-length regression constants are summarized in Table 2.

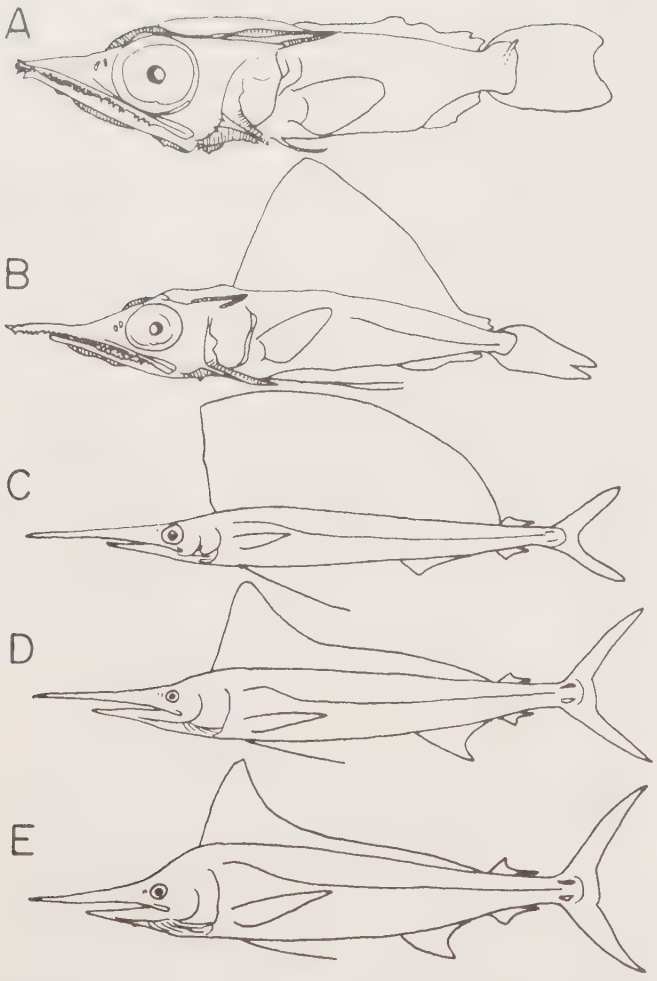

Figure 1.—Ontogenetic change in body form of striped marlin. A. 7.9 mm SL, B. 21.2 mm SL, C. 121.5 mm body length, D. 1,050 mm body length, E. 1,882 mm body length. (From Nakamura, 1968.)

1.32 Cytomorphology

No data available.

1.33 Protein specificity

No data available.

2 DISTRIBUTION

2.1 Total Area

In the eidogical classification of Parin (1968) the striped marlin is holoepipelagic, i.e., it inhabits the isothermic surface pelagic layer of the ocean at all stages of its life cycle. Such species are chiefly limited in distribution to the tropics, where a permanent thermocline exists, but penetrate higher latitudes in the warm season. Atypical of the distribution of most scombroids, the striped marlin seems to prefer the more temperate waters. In the Pacific the distribution resembles that of the albacore, *Thunnus alalunga*, and bluefin tuna, *T. thynnus*, in contrast to that of the other billfishes and tunas (Howard and Ueyanagi, 1965; Parin, 1968), however, in the Indian Ocean the striped marlin distribution is centered in warmer waters.

Striped marlin occur throughout the warmer waters of the Indian and Pacific oceans. The species ranges eastward to the coast of the American continents and westward to the African coast. Off South Africa they are found a slight distance into Atlantic waters (Talbot and Penrith, 1962). Extreme poleward distribution has been recorded to lat. 40°-45° in both hemispheres. In the north this occurs in the Kuroshio extension, primarily between long. 165°E and 180°, but also at long. 150°W (Fisheries Agency of Japan, Research Division, 1969-71). In the southern hemisphere this occurs in the Agulhas Current (Talbot and Penrith, 1962; Fisheries Agency of Japan, Research Division, 1969-72) and also rarely at long. 105°E (Fisheries Agency of Japan, Research Division, 1969), which appears to be West Wind Drift water. On the eastern perimeter of the Pacific, Point Conception (lat. 35°N) and Chañaral, Chile (lat. 29°S) appear to be the northern and southern limits of distribution.

The broad geographical distribution of this species makes it difficult to generalize on the physical and biological characteristics of the areas inhabited. Temperature, however, is one parameter which has been considered to influence total distribution. The 20° and 25°C isotherms tend generally to bound the total distribution at least in the western Pacific (Howard and Ueyanagi, 1965).

2.2 Differential Distribution

2.21 Spawn, larvae, and juveniles

Although information is lacking on the distribution of eggs, there are several reports (Ueyanagi, 1959, 1964; Jones and Kumaran, 1964; Nishikawa and Ueyanagi, 1969) pertaining to the distribution of larvae.

In the Pacific, larvae have been observed in the northwestern Pacific (west of long. 180°) between lat. 10° and 30°N; and in the South Pacific (west of long. 130°W) between lat. 10° and 30°S. The larvae are most abundant in early summer, with the peak occurrence in the northwestern Pacific during May-June, and in the South Pacific in November-December. The seasonal occurrence of mature females coincides with that of the larvae (Ueyanagi, 1964). While the distribution of larvae is not known for the

Table 2.—Weight-length constants for *Tetrapturus audax* (log W = log a + b log L).

Location	Weight	Units of weight	Length	Units of length	Number	Approximate length range of specimens	a	b	s	Source
New Zealand and Australia	Whole	lb	FL[1]	cm	27	265-310	−6.515	3.624	0.045	Gregory and Conrad, 1939 (after Royce, 1957)
New Zealand	Whole	lb	FL[1]	cm	48	218-310	−5.024	3.011	0.056	Morrow, 1952a (after Royce, 1957)
Central Pacific	Whole	lb	FL	cm	13	142-304	−6.648	3.691	0.502	Royce, 1957
Hawaii	Whole[2]	lb	FL[3]	cm	30	166-253	−6.110	3.446	0.048	Hawaii Division of Fish and Game (after Royce, 1957)
East Africa	Whole	lb	FL	cm	98	170-270	−4.629	2.844	?	Williams, 1967
Fiji area	Gilled and gutted	kan[4]	Eye-fork[2]	cm	562	160-260	−6.737	3.504	?	Koga, 1967
Equatorial west Indian Ocean	Whole	lb	Eye-fork	cm	156	120-196	−4.782	[5]3.062	?	Merrett, 1968c
Eastern Pacific	Whole	kg	Eye-fork	cm	51	108-211	−5.255	3.089	?	Kume and Joseph, 1969b
Eastern Pacific	Whole	lb	Eye-fork	cm	1,982	110-215	−4.816	3.072		Wares and Sakagawa, 1974
Eastern Pacific	Whole	kg	Eye-fork	cm	1,982	110-215	−5.157	3.071		Wares and Sakagawa, 1974
Eastern Pacific	Whole	lb	FL	cm	535	153-271	−5.007	2.986		Wares and Sakagawa, 1974
Eastern Pacific	Whole	kg	FL	cm	535	153-271	−5.340	2.982		Wares and Sakagawa, 1974

[1]The original measurement was SL which apparently Royce converted to FL on the basis of regression for nine Hawaiian specimens and mislabeled "*total*" length in caption to Appendix Table 3-A.

[2]Presumed.

[3]The original measurement was naris to fork which Royce converted to FL on the basis of regression for 21 Hawaiian specimens.

[4]1 kan = 3.75 kg = 8.287 lb.

[5]±0.197.

eastern Pacific (east of long. 120°W), mature fish are reported to occur there between lat. 5° and 20°N, largely in May-June (Kume and Joseph, 1969b).

In the Indian Ocean, larvae have been reported to occur in the Banda and Timor seas during January to February (Ueyanagi, 1959), and in the western Indian Ocean during December to January between lat. 10°S and 18°S and in the eastern Indian Ocean during October to November between lat. 6°N and 6°S (Jones and Kumaran, 1964). Mature females are reported to occur in March-May in the Bay of Bengal although larval occurrence is not yet known there (Ueyanagi, 1964).

The lower temperature limit in the distribution of larvae is approximately 24°C both in the Indian and Pacific oceans. However, the distributions differ in that in the Pacific the larvae are scarcely found in equatorial waters. It is noted that striped marlin larvae are not likely to appear in the Kuroshio area, while sailfish larvae occur there exclusively (Ueyanagi, 1959).

Information is very sparse on the distribution of the juveniles. Nakamura (1968) reported on two juveniles (body length, 12.15 and 14.5 cm) found in stomachs of a yellowfin tuna, *Thunnas albacares*, and a dolphin, *Coryphaena hippurus*, taken by longline. One juvenile was found on 13 January 1955 at lat. 23°52′S, long. 175°49′W and the other on 21 December 1964 at lat. 17°57′S, long. 67°29′E. These two occurrences coincide with larval distributions in the South Pacific and Indian Ocean, respectively.

2.22 Adults

Major areas of high abundance are the western Arabian Sea, the central North Pacific (lat. 15°-30°N) and the eastern Pacific as shown in Figure 2. This figure shows distributions based on highest quarter-year hook rates by 5° squares for the years 1967-69 (Fisheries Agency of Japan, Research Division, 1969-72). Lesser areas of abundance occur off South Africa, northern Madagascar, northern Sumatra, Sri Lanka, eastern and western Australia, central Pacific coast of Japan, and the south central Pacific.

The high density in the Arabian Sea appears to be seasonal, occurring in the second quarter of the year. However, fishing effort in other seasons has been very slight. Off East Africa (lat. 0°-12°S) where striped marlin are the most abundant marlin, the works of Merrett (1968a, b) showed highest hook rates occurred between lat. 2° and 4°S. The hook rate was six times higher in the northeast monsoon (Nov.-Mar.) than in the southeast monsoon (Apr.-Oct.).

The season of high abundance off western and eastern Australia is the fourth quarter (Fisheries Agency of Japan, Research Division, 1969-72). Koga (1967) states, however, that good catches occur in winter off western Australia. In the South Pacific, Koga states that it is a remarkable feature that the main fishing areas, which show good catches from August to December, show very poor catches from January to July.

In the northwestern Pacific, striped marlin are abundant in Formosan waters, both in the Kuroshio and in the South China Sea, during the whole northeast monsoon season with a peak in the middle of that season. Later in the spring, they move north into the waters of Japan where they appear at about the same time as the albacore do (Nakamura, 1949).

In the Hawaiian area, striped marlin occur from fall through spring with the seasonal distribution being

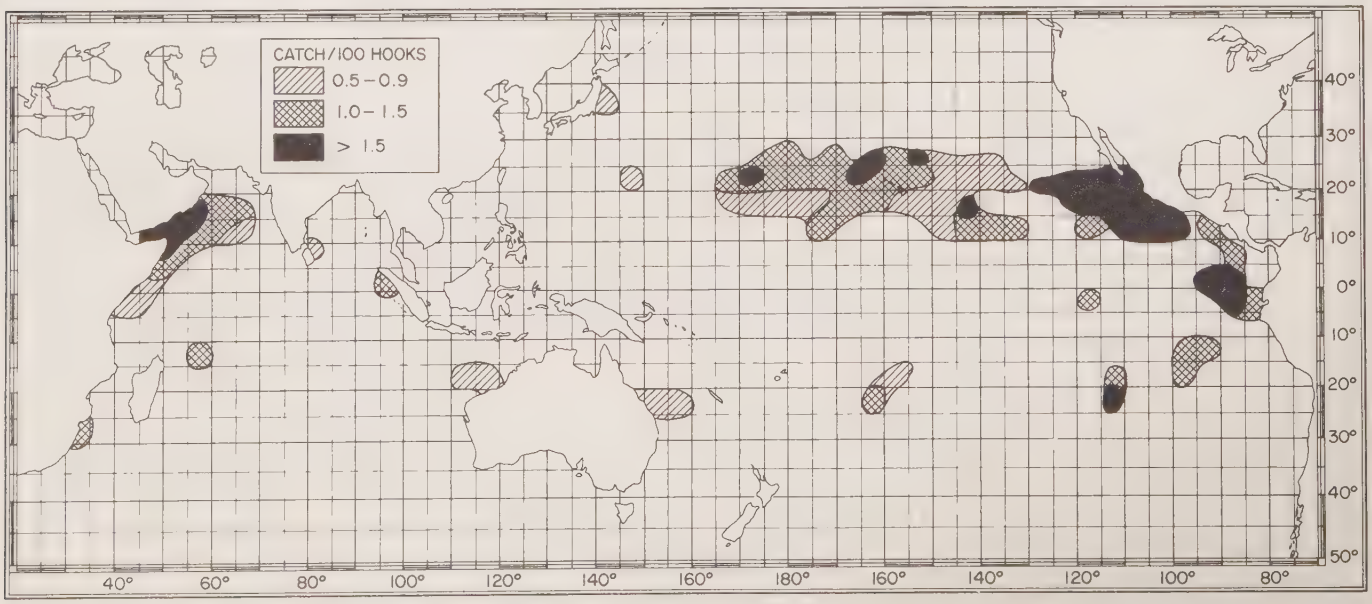

Figure 2.—Areas of high apparent abundance of striped marlin, 1967-69. (After Fisheries Agency of Japan, Research Division, 1969-72.)

complimentary to that of the blue marlin, *Makaira nigricans*, which occurs primarily in the summer (Strasburg, 1970).

In the eastern Pacific, striped marlin are present throughout the year from lat. 30°N to 30°S. High abundance is maintained throughout the year in the areas of the Revilla Gigedo Islands, Baja California, Ecuador, the Galapagos Islands, and in the high-sea area bounded by long. 90°-110°W and lat. 10°-30°S (Kume and Joseph, 1969b). Seasonal changes in apparent density are marked. The concentration between Baja California and the Revilla Gigedo Islands, which is restricted to a narrow band in the first quarter, expands southeast along the coast and seaward to long. 115°W during the second quarter, and then north to lat. 28°N, south to lat. 3°N and seaward to long. 125°W during the third quarter. During the fourth quarter the southern extension expands further to long. 130°W. Another seasonal concentration develops in the second and third quarters in the offshore area between long. 100° and 115°W centered at about lat. 8°-13°N. The area of high density around the Galapagos Islands extends eastward to the coast of Ecuador in the third and fourth quarters and then recedes again in the first.

The sport fisheries for striped marlin off Mexico and southern California are seasonal. In southern California it is highly seasonal with almost all fish being taken between August and October. In Mexico some fish may be taken year round, but the best fishing occurs from December through March at Mazatlán and April through August near the tip of Baja California (Eldridge and Wares, 1974).

In addition to differential distribution in density, there is also some differential distribution in size. In the eastern Pacific, fish on the southern spawning grounds are larger than those on the northern. The length frequency of the southern group has a single mode at 180-200 cm whereas that of the northern group has two modes, one at 140 cm and one at 180 cm (Kume and Joseph, 1969b). In the western Pacific latitudinal stratification occurs. Honma and Kamimura (1958) show small marlin occurring in equatorial waters; these small fish are absent in the region of lat. 5°-16°S. In mid-latitudes (15°-30°S) of the central South Pacific longitudinal stratification is apparent; larger fish (> 180 cm) occur in the western Pacific (Koga, 1967). There may also be some vertical stratification. Furukawa, Koto, and Kodama (1958) found harpooned fish to be larger than longline-caught fish in the East China Sea. The harpooned fish were also fatter at a given length.

Off Formosa the smaller fish, which were long thought to be the separate species *Kajikia formosana*, occur with the shortbill spearfish, *Tetrapturus angustirostris*, offshore from the center of the Kuroshio, while the larger fish occur inshore (Nakamura, 1949).

2.3 Determinants of Distribution Changes

Probably behavioristic factors related to feeding and reproduction are the primary determinants of changes in distribution. These in turn are affected by the seasonal cycle of warming of the surface waters, development of thermoclines and currents, and seasonal cycles in abundance of food organisms. The subject of the factors and relationships causing concentration of striped marlin has not received much discussion in the literature.

Nishimura and Abe (1971) have found a correlation between the position of the Kuroshio as indicated by the latitude at which the current crosses 139°30′E, and the catch made off Izu.

Kume and Joseph (1969b) noted that the appearance of the area of high hook rate centered at lat. 8°-13°N from long. 100° to 115°W is associated with the strong development of the Equatorial Countercurrent. They noted further that a diagonal band of high abundance extending from lat. 5°S, long. 120°W to lat. 8°S, long. 95°W was in the general region of the eastern extension of the South Equatorial Countercurrent.

In the area west of Australia, both the striped marlin and southern bluefin tuna grounds are centered at the boundary of currents which run along long. 115° E meridian in winter (Koga, 1967).

Manning (1957) states that off Chile, striped marlin are found in the green water that is normally found from shore to 10 to 25 miles offshore. Their occurrence in these waters was in common with bonito, sardines, and anchovies and in contrast to swordfish which occurred farther offshore in the blue and white waters.

Furukawa et al. (1958) show the fishing ground in the western Pacific associated with the surfacing of the 20°C isotherm over the edge of the continental shelf.

Nakamura (1938) states that surfacing of fish is associated with high waves generated by opposing wind and current as in the case of the Kuroshio and the northeast monsoon.

2.4 Hybridization

No record.

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

Striped marlin are heterosexual with no reported intersexuality or hermaphroditism.

Sexual disorphism has not been reported in this species and the sexes are indistinguishable externally. Nakamura (1949) mentioned the sexual difference in body size is not great in the genus *Tetrapturus* in contrast to the case in *Makaira*. Differences in greatest

size or modal size between the sexes are small. Ueyanagi (1953) found, in the northwestern Pacific, that the modal size of males is about 10 cm smaller than that of females. Koga (1967) showed a length-frequency distribution by sex for 210 fish from the Fiji area in which the modal lengths for males and females were 195 and 205 cm, respectively. In a sample of 105 striped marlin taken by longline off East Africa, Williams (1967) found males did not exceed 240 cm fork length (equivalent to 182 cm eye-fork length from regression of Merrett, 1971). About 16 females were taken above this length to a size of about 270 cm (205 cm eye-fork length). Merrett (1971), however, found males up to 193 cm eye-fork length off East Africa. Modal size differences between the sexes were not found in Hawaiian fish (Strasburg, 1970) nor in the eastern Pacific (Kume and Joseph, 1969b).

3.12 Maturity

As has been found in other pelagic species such as albacore and dolphin, quantitative measure of maturity for males is difficult. There is only a small increase in testis size during the maturation cycle. Merrett (1971) found little correlation between relative testis size and maturity-stages based on microscopic examinations. In fact, Merrett (1970) suggests that there is continuous availability of spermatozoa in mature males based on differential maturation of the testicular lobules and the possession of a muscular seminal vesicle.

In the female, maturation is synchronous throughout the ovary and seasonal maturation is accompanied by marked increase in relative size of the gonads. Data from Kume and Joseph (1969b) showed a twentyfold increase. Moreover, there is good correlation of relative ovary weight and mean maximum egg diameter (Merrett, 1971; Eldridge and Wares, 1974).

Williams (1967) concluded from longline data in East Africa that first maturity was reached between 180 and 200 cm fork length (50-80 lb) which is equivalent to 141-157 cm eye-fork length (Merrett, 1971). Merrett reported similar results, 140-160 cm or 62-93 pounds. Ueyanagi (1957b) mentioned that 154 cm eye-fork length was the smallest size found in the spawning group of the northwestern Pacific. Kume and Joseph (1969b), using a gonad index, reported that individuals from the eastern Pacific do not regularly enter the spawning group until reaching about 160 cm eye-fork length but found one as small as 148 cm. Other data from the eastern Pacific (Eldridge and Wares, 1974) agree with these conclusions.

Since age at specific size is not known for striped marlin, age at maturity is also unknown. Koga (1967), however, stated "it is likely that growth rate of this species shows different values between the Indian Ocean and the Pacific Ocean and the groups in the Indian Ocean attain maturity earlier than those in the Pacific."

3.13 Mating

Nothing has been published relating to mating habits of this species.

3.14 Fertilization

Fertilization is externally.

3.15 Gonads

Merrett (1970) has described the gonads of billfish in detail. The following description is taken from his work.

> The gonads are paired organs lying in the posterior half of the body cavity, on each side of the stomach and intestine. They are suspended from the lateral edges of the chambered air bladder by mesenteries . . . the gonads are almost bilaterally symmetrical and both terminate at their point of discharge to the exterior in the urino-genital papilla . . . which lies posterior to, and in a common groove with, the anus . . . The urinary and genital systems are closely linked.
>
> The ovaries are elongate sausage-shaped organs, which taper at both ends, and joined only at their posterior ends . . . A strong muscular sheath binds the ovaries to the urino-genital papilla and the basal part of the intestine. They are invested in thick layers of connective tissue which sometimes contain deposits of fat; fat is also occasionally found in the mesovarium. Beneath the connective tissue the ovaries are pale flesh-pink to wine red in colour, depending upon the stage of maturity. Internally, at certain stages, a central lumen runs the length of the ovary . . . the ovaries have been found to be unequal in length . . . either ovary can be the longer of a pair.
>
> . . . Immediately posterior to . . . [the anal papilla] . . . is the urino-genital papilla. In the female this carries only the urinary duct. The point of discharge of the ovaries is situated between the bases of the anal papilla and the urino-genital papilla.

This opening between the anal and urino-genital papillae which is absent in the males should serve as an external characteristic in distinguishing the sexes. But in the experience of the junior author this difference is difficult to observe consistently in this species. It is more obvious in the sailfish.

Nakamura (1949) stated that the fecundity of billfishes ranges from 1 to 1.2 million eggs, depending on fish size and species. Morrow (1964) estimated 2 million eggs for New Zealand marlins. These appear to be low estimates, however. Merrett (1971) reported an estimated fecundity of 12 million for one Indian Ocean specimen of 182 cm eye-fork length, 126 pounds with ovary weight of 1.53 kg, and mean maximum egg diameter of 0.470 mm. Eldridge and Wares (1974) reported fecundity estimates of three eastern Pacific specimens which ranged from 11 to 29 million eggs. These fish ranged in size from 150 to 180 cm eye-fork length but the fecundities showed no relation to size of the fish. Gosline and Brock (1960) estimated 13.8

million eggs were contained in one ovary of a 154-pound striped marlin landed in Honolulu. The other ovary of this fish was immature.

3.16 Spawning

Examination of size-frequency distributions of egg diameters (Eldridge and Wares, 1974) indicates only one spawning per season.

In the western Indian Ocean it appears that the high catch rates during the northeast monsoon period which peak from December to February are associated with a postspawning feeding migration (Williams, 1967; Merrett, 1971). Spawning must occur elsewhere in the Indian Ocean.

From larval occurrence, spawning was suggested to take place in the Banda and Timor seas during January to February (Ueyanagi, 1959). On the basis of larval occurrence, Jones and Kumaran (1964) stated that striped marlin spawn in the western Indian Ocean during December-January between lat. 10° and 18°S and in the eastern Indian Ocean during October-November between lat. 6°N and 10°S. Furthermore mature females are known to occur in March-May in the Bay of Bengal and in October-December in the waters south of the Lesser Sunda Islands (Ueyanagi, 1964).

In the western Pacific, mature females are found from lat. 15° to 30° (north and south) in early summer, from May to June and October to January in the northern and southern hemispheres, respectively. Larvae are also found in these areas (Ueyanagi, 1964). Nakamura (1949) stated that in the Formosa area, spawning is thought to take place mainly in the South China Sea with its peak occurring from April to May. Koga (1967) reported that the spawning areas (lat. 18°-30°S) in the western South Pacific is also the main fishing area and that the period of spawning corresponds to the season of northward migration which occurs from September to November.

In the eastern Pacific, the spawning season also appears to be the early summer in each hemisphere, quarters II and III in the northern and quarters IV and I in the southern. Highest frequencies of spawning fish occur from May to June in the north and November to December in the south (Kume and Joseph, 1969b). Evidence of spawning in the eastern Pacific is based only on relative gonad sizes of females. The northern spawning area appears to be isolated in a narrow band from long. 107° to 114°W extending from about lat. 6° to 19°N (Kume and Joseph, 1969b).

Ovaries of striped marlin caught in the Mexican sport fishery undergo rapid development in June; ripe fish were never observed (Eldridge and Wares, 1974). Japanese fishermen, however, have reported ripe and running ripe striped marlin in the waters around Socorro Island from June to October (J. L. Squire, Jr., Southwest Fisheries Center, National Marine Fisheries Service, NOAA, La Jolla, Calif., pers. commun.).

The southern spawning area appears fairly well confined to lat. 20°-25°S and long. 125°-130°W (Kume and Joseph, 1969b). Highest frequencies of the mature females occur in November and December.

Nakamura (1949) stated that sex ratios approached 1:1 at the peak of the spawning season. However, it was found that males dominate during the spawning season in the northwestern Pacific (Nakamura, Yabuta, and Ueyanagi, 1953). Kuma and Joseph (1969b) also found a high proportion of males in the spawning groups in the eastern Pacific. Male:female ratios ranged from 1.8 to 6.6 in spawning groups, whereas in nonspawning groups they tended to be less than 0.5 and to decrease with increased size of fish.

3.17 Spawn

There is little information pertaining to the eggs of this species. Nakamura (1949) mentioned that the external morphology of the eggs of striped marlin closely resembles that of sailfish eggs which are spherical, transparent, and buoyant, with a single oil globule and with no special structure on the egg membrane. Morrow (1964) reported that the ovarian eggs of striped marlin from New Zealand average about 0.85 mm in diameter. Size of the ovulated eggs of this species is presumed to exceed 1 mm in diameter considering that the mean diameter of eggs for shortbill spearfish is 1.442 mm and for sailfish is 1.304 mm as reported by Merrett (1970).

3.2 Pre-Adult Phase

3.21 Embryonic phase

No information available.

3.22 Larval phase

The postlarval stage of striped marlin is described in detail by Ueyanagi (1959). The study was based on 40 specimens ranging from 2.9 to 21.2 mm in standard length, collected from the northwestern Pacific, South Pacific, and the Indian Ocean. These specimens were captured by surface tows of the larvae net. The morphology of the striped marlin postlarvae is similar to that of other istiophorid species in the development and degeneration of head spination, fin formation, pigmentation, etc. Figure 3 from Ueyanagi (1959, 1963a) represents the postlarval stage of this species from an early stage with short snout to an advanced stage with elongated jaws. The snout begins to lengthen at around 7 mm standard length. Head spination becomes most conspicuous at this size. Fin rays of each fin reach their full complement at around 20 mm standard length. Pigmentation extends almost all over the body surface and on the dorsal fin membrane at this size. The dorsal fin begins to increase its height at around 10 mm and stands very high like a sail in larvae exceeding 20 mm. The key diagnostic character for the striped marlin larvae was reported as

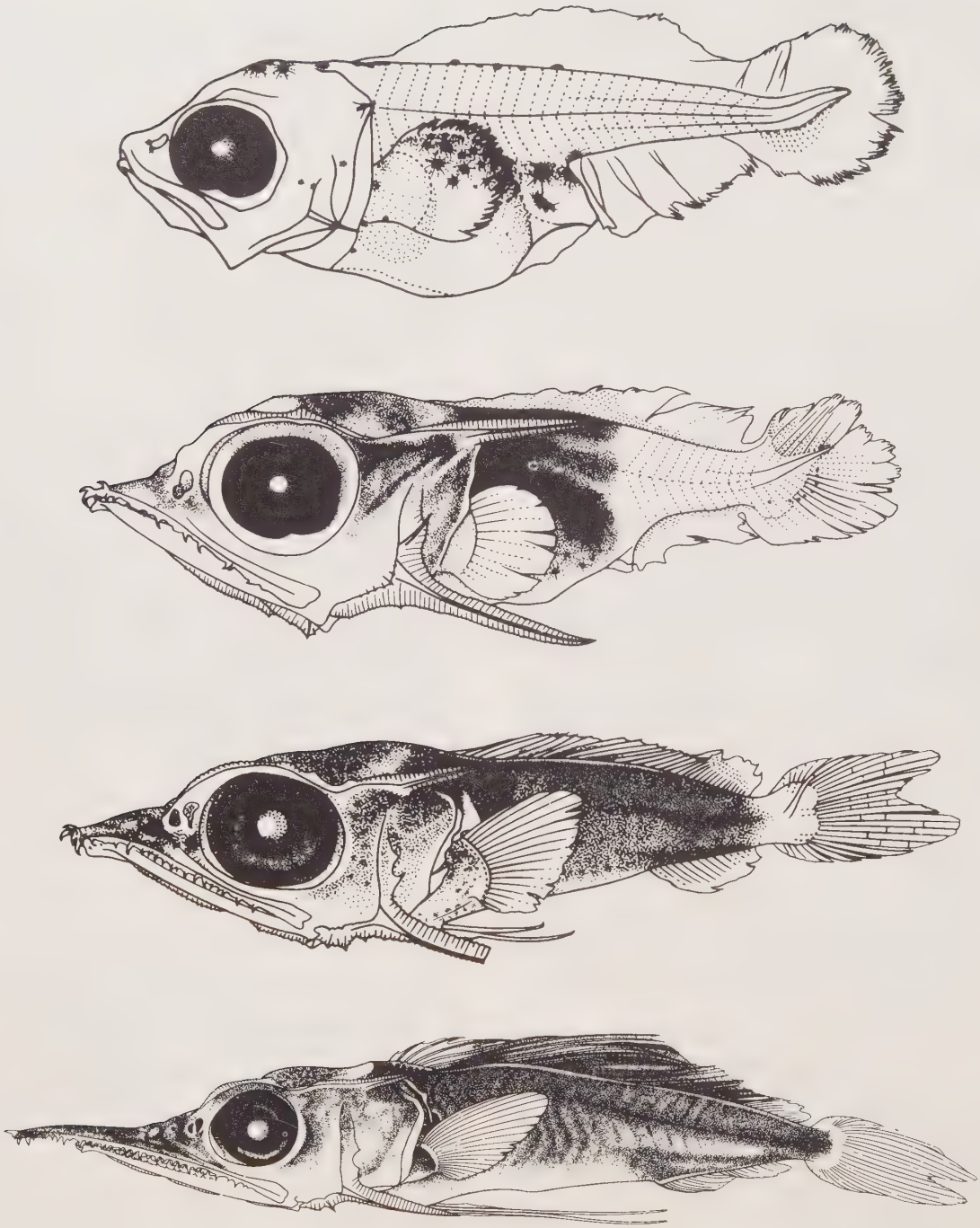

Figure 3.—Larvae of striped marlin. From top to bottom: 2.9, 5.0, 12.0, and 21.2 mm SL. (From Ueyanagi, 1959, 1963a.)

follows: ". . . the profile of head, tip of snout and center of eye are on a nearly equal level" (Ueyanagi, 1963a). In addition, the shape (arrangement) of the pterotic and preopercular spines is diagnostic for larval identification (Ueyanagi, 1974).

On the vertical distribution of billfish larvae, Ueyanagi (1964) indicated that larvae appear to be distributed most abundantly in the surface layer during the daytime and vertical, diurnal migration seems to occur in the upper 50 m of waters (Table 3.). Billfish larvae appear from time to time in the stomach contents of the larvae and juveniles of sailfish and swordfish, *Xiphias gladius* (Arata, 1954; Gehringer, 1956). It is assumed that striped marlin larvae are therefore preyed upon by many surface feeding species, including the billfishes. Considering the very large numbers of eggs spawned by the striped marlin (see 3.15), it appears that mortality at the larval stage is extremely high.

Time of first feeding: No direct information is available. There is an observation that five copepods were seen in the stomach of a 3.9-mm sailfish larva (Gehringer, 1956).

Type of feeding: There is no information pertaining to the larvae of striped marlin. Of the larvae of sailfish in the Atlantic, Gehringer (1956) noted that "copepods constituted the food of specimens less than 6 mm. long. At this size fish larvae also were eaten, and no specimen exceeding 13 mm. had copepods in its stomach." Furthermore, it is also known that sailfish larvae have consumed istiophorid larvae half as long as their own body length. It is believed that the larvae of striped marlin, like the sailfish, begin to feed on fish larvae after reaching a size of about 7 mm.

Table 3.—Comparison of numbers (and percentage) of tows from which istiophorid larvae were captured, showing the various depths and times of towing, in the western Pacific area. (From Ueyanagi, 1964.)

Depth (m)	32 day tows		31 night tows	
	Number	Percent	Number	Percent
0	22	68.8	12	38.7
ca. 20	8	25.0	12	38.7
40-50	2	6.2	10	32.3

3.23 Adolescent phase

Nakamura (1968) described the juveniles of striped marlin based on two specimens collected from the South Pacific and the western Indian Ocean (see 2.21). His drawing has been reproduced as Figure 4. In the juvenile stage the snout is very elongate and, in fact, is longest at this stage relative to body length. The shape of the first dorsal fin still differs from the adult configuration, being highest anteriorly and decreasing gradually in height posteriorly. The arrangement of the viscera is similar to that of the adult. Nakamura also mentioned that the juvenile of striped marlin is similar to that of the white marlin in many respects except that the former has no ocelli on the first dorsal fin.

It is believed that large, powerful pelagic fishes such as tunas, billfishes, dolphins, etc., are the principal predators of juvenile striped marlin.

Little is known about parasites in juvenile striped marlin.

Immature striped marlin (80-100 cm eye-fork

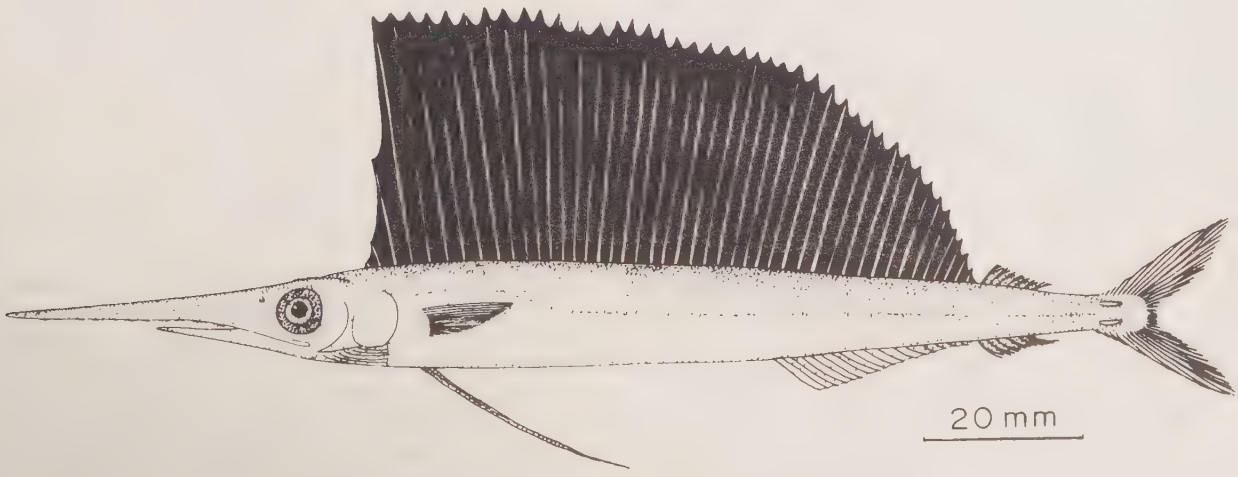

Figure 4.—Juvenile striped marlin (121.5 mm body length) collected from the southwestern Indian Ocean. (From Nakamura, 1968.)

length) are taken by longline. The shape of the first dorsal fin in these fish differs from the adults in that the posterior rays are still high (Ueyanagi, 1957b). Fish and squid are found in the stomachs, as in the adults.

Following the 1954 hydrogen bomb test in Bikini, it was reported that virtually all of the radioactively contaminated striped marlin found in the northwestern Pacific were fish under 130 cm long (Anon., 1955). It is not clear what the implications are with respect to ecological differences between young and adult fish.

3.3 Adult Phase (Mature Fish)

3.31 Longevity

The ability to determine age of individual striped marlin has not been developed and thus life tables cannot be developed and life expectancy and maximum age are unknown.

Koto (1963a), using size-frequency data from western Pacific catches, was able to discern six age classes (which he designates as n though $n + 5$) in fish greater than 100 cm eye-fork length. The Walford growth transformation of his data indicated an ultimate size of about 290 cm. Specimens of this size are apparently occasionally taken in the South Pacific (Honma and Kamimura, 1958). From the general pattern of growth indicated by Koto, fish of this size would be expected to be at least 10 yr old.

3.32 Hardiness

Very little is known. Because of the large size and activity of this species, physiological experimentation is difficult. The return rate for tagged fish is much higher for striped marlin than for sailfish (Squire, 1974), and this may indicate greater general hardiness for striped marlin. Healing of severely broken bills (Wisner, 1958) may also be an indication of hardiness. Sportsmen usually report that the striped marlin fights harder than the sailfish when hooked and tends not to die as easily as the sailfish.

3.33 Competitors

The other billfishes, particularly the smaller species (sailfish and probably the shortbill spearfish), swordfish, and the larger tunas are probably the closest competitors for food. Even the smaller scombrids share many forage species with the striped marlin. The dolphin and pelagic sharks such as *Prionace*, *Carcharhinus*, and *Isurus* utilize many of the same forage species (Parin, 1968). Striped marlin tend to feed more on epipelagic species and less on mesopelagic species than the oceanic tunas or the swordfish.

3.34 Predators

Predators of adults are probably extremely limited, the only likely candidates being some of the large pelagic sharks and the toothed whales.

Bills of billfishes have been found in floating objects and other fish. Occasionally bills of striped marlin are found to have been broken off, and the fish are known sometimes to ram fishing boats when hooked, but it is not certain that any of these occurrences have any relation to defense or aggressive action.

3.35 Parasites, diseases, injuries, and abnormalities

Parasites and diseases: The body surface usually harbors many caligoid copepods which frequently congregate on the ventral surface, particularly in the area around the anal fin and on the head. Williams (1967) reports they may occur in the thousands. The skin surface in areas of concentration often appears red and irritated. Penellid copepods (*Penella fillosa*) are frequently found penetrating the skin and anchored in the muscle or sometimes in internal organs such as the gonads. Koga (1967) reports the percentage occurrence of caligoid copepods and penellid copepods on striped marlin in Fiji waters was 100% and 20%, respectively. Eldridge and Wares (1974) report the percent occurrence of penellids above and below the lateral line on one side of the body as 26.2% and 22.8% with average infections of 3.3 and 2.3 copepods per fish. Stalked barnacles (*Conchoderma irgatum*) frequently are attached to the penellid copepods and often to the marlin skin, normally near the vent (Williams, 1967). Digenetic trematodes were reported found on the gills by Williams (1967). Monogenetic trematodes of the family Capsalidae are quite common on the surface of the skin (Eldridge and Wares, 1974).

Cestode worms resembling *Dibothrium manubriformes* have been found in the intestines and nematodes (*Contracaecum incurvum*) are very common in the stomach occurring in densities greater than 200 per stomach (Morrow, 1952b). The copepod, *Philichthys xiphiae*, has been found in the mucus canals of the preopercular and opercular bones, and capsalid trematodes are commonly found in the nasal capsule (Eldridge and Wares, 1974).

Injuries and abnormalities: Gastric ulcers were reported in 14% of 563 eastern Pacific striped marlin (Evans and Wares, 1972). These may be associated with the presence of nematodes (R. T. B. Iversen, Southwest Region, National Marine Fisheries Service, NOAA, Honolulu, Hawaii, pers. commun.). The small squaloid shark (*Isistius brasiliensis*), the probable cause of crater wounds on many pelagic fishes including istiophorids (Jones, 1971), probably parasitizes striped marlin.

There is evidently little ability for regeneration as

broken bills and pelvic fins are seen to heal over rather than regenerate. Striped marlin have recovered after losing almost all of the bill (Wisner, 1958).

3.4 Nutrition and Growth

3.41 Feeding

Most active feeding probably takes place in the morning. LaMonte (1955) reported that squid found in the stomachs of striped marlin off Peru and Chile were less digested in fish caught in the morning than those landed after noon. Kobayashi and Yamaguchi (1971), examining only fish caught after noon, found a decline in feeding activity toward sunset. Williams (1967), however, suggests that East African fish feed at any time of the day or night.

Apparently the food is usually captured by grasping with the mandibles rather than by spearing, slashing, or clubbing with the bill. Fish which have lost the bill completely survived well. Some food specimens are occasionally found, however, which have been neatly speared (Wisner, 1958; Evans and Wares, 1972).

3.42 Food

Several authors have reported on food habits. Table 4 gives an idea of the variety of food species which have been found most important in different studies. It is notable that, despite the large size and lack of gill rakers in striped marlin, relatively small forage items are commonly taken (Nakamura, 1949).

Food habits do not appear to vary appreciably with sex or size over the range of sizes commonly caught. Considerable variation in species composition of the diet occurs, however, with season and geographic location (Evans and Wares, 1972). Such variations probably reflect variations in availability of the food organisms in keeping with the generally accepted concept that these fish are broadly carnivorous, nonselective feeders. This is true of epipelagic fishes generally (Parin, 1968).

The average volume of food found in stomachs of striped marlin caught by the eastern Pacific sport fishery ranged from 14 to 23 fluid ounces per stomach (Evans and Wares, 1972). Yamaguchi (1969) reports that empty stomachs were found in 66% of striped marlin caught by longline. This percentage tends to be larger in billfish than in tunas. Evans and Wares (1972) found 19% empty stomachs.

Table 4.—Some reported major food species for striped marlin.

Area	Food species	Author
East Africa	*Fistularia* sp. *Auxis* sp. Squid	Williams, 1967
New Zealand	*Scomberesox saurus* *Arripis trutta* *Loligo* sp.	Morrow, 1952b
New Zealand	*Ommastrephes sloani* *Caranx lutescens* *Scomber japonicus*	Baker, 1966
Tasman Sea	*Alepisauridae* *Clupeidae*	Koga, 1968
Bonin Islands	*Gempylus* sp. Cephalopods *Pseudoscopelus* sp. *Alepisaurus* *Ostracion* Crustacea	Yabuta, 1953
California	*Cololabis saira* *Engraulis mordax* *Sardinops caerulea*	Hubbs and Wisner, 1953
California	*Engraulis mordax* *Trachurus symmetricus*	Evans and Wares, 1972 Craig, 1972
Mazatlán, Mexico	Squid *Etrumeus teres* *Fistularia* *Argonauta* sp.	Evans and Wares, 1972
Baja California, Mexico	Squid *Etrumeus teres* *Scomber japonicus* *Fistularia* sp.	Evans and Wares, 1972
Peru-Chile	Squid	LaMonte, 1955
Chile	*Engraulis ringens* *Trachurus symmetricus* Squid	de Sylva, 1962

3.43 Growth rate

Weight-frequency modal progressions in Hawaii landing data suggest an annual growth rate of about 30 pounds (Royce, 1957). Merrett (1971) found agreement with Royce's data in size-frequency distributions from East Africa. Possible modal lengths of about 152, 167, 177, and 197 cm eye-fork length were found in the length-frequency distribution for the total catch. Computed weights at modal lengths gave annual weight increments of 27, 21, and 23 pounds.

Koto (1963a) working with length-frequency data from the western North Pacific, found six modal groups (n though $n+5$). The monthly progression of these modes is shown in Figure 5. The designations of these modal groups are as follows:

Group	*Lengths* (cm)	*Increment* (cm)
n	100-120	?
$n+1$	120-160	35
$n+2$	160-185	27
$n+3$	185-205	19
$n+4$	205-220	16
$n+5$	220-233	13

There is a marked seasonal change in growth rate with rapid growth occurring from June to November and very little growth in the remainer of the year for age groups $n+1$, $n+2$, and $n+3$. Age group n appears

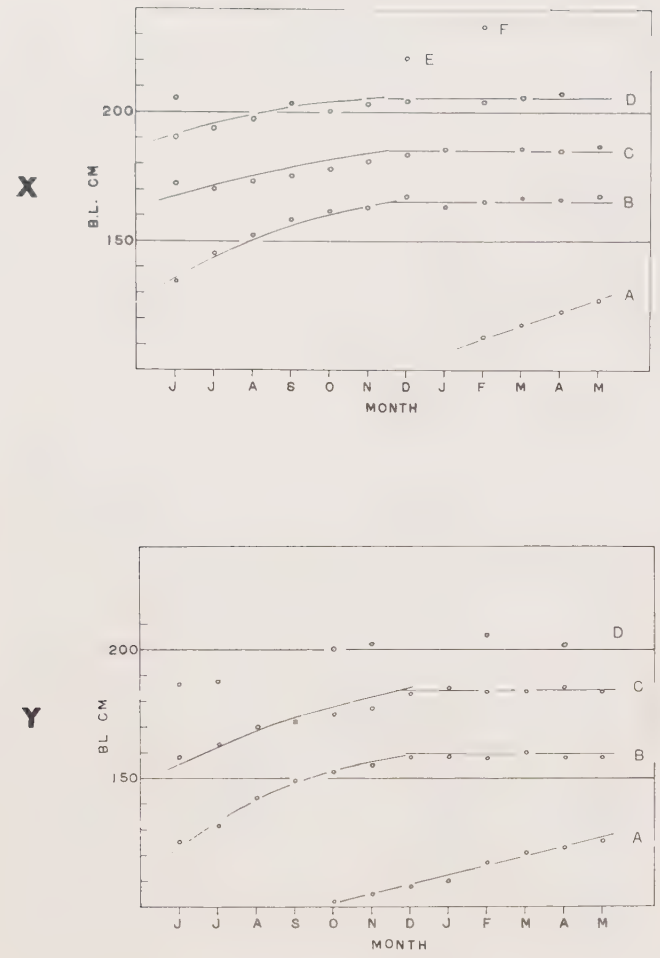

Figure 5.—Seasonal changes in modes derived from average year's length frequencies of longline-caught striped marlin. A. North Pacific Current area; B. East China Sea (long. 120°-130°E). (From Koto, 1963a.)

in the catch only after September, as fish larger than 100 cm and shows rapid growth right through the winter. The failure of the fishery to capture many fish below 100 cm makes it impossible to say what the absolute ages of the groups are.

The annual growths of the $n+1$ and $n+2$ age groups differ between areas and years. Koto (1963b) showed that in the North Pacific Current area the yearly differences in the length composition were caused by differences in the average length of the $n+1$ age group. In the North Equatorial Current area, however, these differences were probably caused by differences in age composition and the relative abundance of the n and $n+1$ age groups.

Koto (1963b) has shown growth rate to be affected by population density. The very close inverse relationship between growth of the $n+1$ age group and the total fish abundance, or especially the abundance of the n and $n+1$ groups is shown in Figure 6. The correlation coefficients between growth of the $n+1$ age group and total fish abundance were -0.958 (df = 6) for the North Equatorial Current area and -0.737 (df = 8) for the North Pacific Current areas.

Royce (1957) suggested the maximum size reached by striped marlin is less than 226.8 kg (500 pounds). Records were given as follows: 172.8 kg (381 pounds) off New Zealand; 142.4 kg (314 pounds) from Pacific equator; a "questionable" record of 196.9 kg (434 pounds) from the Hawaiian market, where normally only occasional specimens approach 136.1 kg (300 pounds); a somewhat questionable record because of possible confusion with the blue marlin of 219.1 kg (483 pounds) from Chile; the world's record, taken off California, was 692 pounds, which was based on a misidentified blue marlin.

The theoretical maximum length of about 290 cm mentioned in section 3.31 is equivalent to 259.5 kg (572 pounds). A fish of 290 cm was taken by longline in the South Pacific (Honma and Kamimura, 1958).

Average semimonthly condition factors (K) computed

$$K = \frac{W \times 10^5}{L^3}$$

where W is whole fish weight in kg
L is eye-fork length in cm

for eastern Pacific fish ranged approximately from 0.80 to 1.26 (Eldridge and Wares, 1974).

In the East China Sea, condition factor

$$K = \frac{W}{L^3}$$

where W = gilled and gutted weight in kan (= 3.75 kg)
L = eye-fork length in m

was found to increase with body length from about 8 at 110 cm to a peak of about 10 at 180 cm and then to decline to about 9 with larger fish up to 230 cm

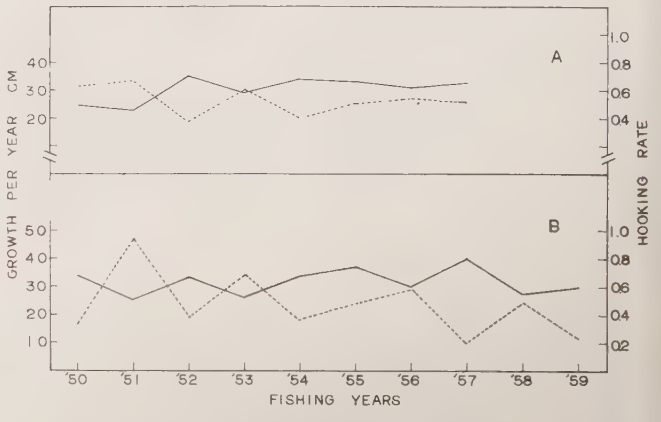

Figure 6.—Relation between total fish abundance and growth of the $n+1$ age group. A North Equatorial Current area; B. North Pacific Current area. ____ growth per year; .....hook rate. (From Koto, 1963b.)

(Furukawa et al., 1958). The condition factor also showed a seasonal drop from about 10.8 in December to about 8.7 in June for fish of body length 166-195 cm. The drop in condition factor before June was much more abrupt than the increase after June. A similar seasonal cycle was also apparent for fish of 136-165 cm.

3.44 Metabolism

There are no data on metabolic rates for this species. Lindsey (1968) found body muscle temperatures as much as 2.6°C higher than the surrounding seawater. The highest temperature recorded occurred near the center of the epaxial muscle mass with a lesser maximum slightly below the hypaxial muscle mass center. Red muscle was found to be lower than white muscle at comparable depths beneath the skin. Temperatures of the viscera exceeded seawater temperatures by 0.7-1.3°C.

Barrett and Williams (1965) report the mean hemoglobin content in 16 striped marlin was 11.3 ± 0.75 g Hb/100 ml and ranged from 5.8 to 16.8.

3.5 Behavior

For feeding behavior, see 3.41; for reproductive behavior see 3.13, 3.21.

3.51 Migrations and local movements

See also 2.22 and 2.3.

The migration pattern of striped marlin appears to be principally a simple latitudinal movement between spawning areas and productive feeding areas (Parin, 1968). The movement is toward higher latitudes in the summer of each hemisphere and back toward equatorial waters in winter. In the northern hemisphere the peak of the northward migration is August-September and the southward migration begins in October and continues through February. The northward movement is also accompanied by an eastward expansion in the eastern Pacific (Howard and Ueyanagi, 1965; Fisheries Agency of Japan, Research Division, 1969-72).

In the central North Pacific small fish of about 13.6 kg (30 pounds) appear in Hawaii in winter, grow to 22.7-27.2 kg (50-60 pounds) by May or June, then migrate north for several months, and return to Hawaii as larger fish the next year. A similar pattern of migration is common to areas west of long. 180° (Howard and Ueyanagi, 1965).

In the southern hemisphere west of long. 150°W fish migrate north from south of lat. 30°S from August through November and form concentrations which are exploited in the area lat. 18°-19°S. The period of this migration corresponds to the spawning season. After November the fish appear to migrate south (Koga, 1967).

In the eastern South Pacific a high density area, which occurs in the area lat. 10°-17°S, long. 90°-115°W during the second and third quarters, appears to move southwest to the region of lat. 20°-28°S, long. 100°-110°W in the fourth and first quarters (Kume and Joseph, 1969a, b).

In the eastern North Pacific the seasonal north-south movements are apparent but less pronounced. Striped marlin do occur in their extreme northern range (southern California) during late summer and fall when surface temperatures reach a peak, but it is not clear whether these fish have come from the south or from the west (Howard and Ueyanagi, 1965). Data from fish tagged in the sport fisheries of southern California and Mexico provide evidence that striped marlin are capable of fairly long migratory movements up to 3,000 miles (Fig. 7). Some fish do move from California southward to the tip of Baja California and further, but there is no evidence of migration from Mexican waters to southern California (Squire, 1974).

Howard and Ueyanagi (1965) suggested on the basis of the appearance of an unusually small size group in California in 1958 and subsequent appearance 2 yr later of a small group in New Zealand, which was of a size expected for fish 2 yr older than the former, that there may be transpacific interchange between these remote areas.

Following the 1954 hydrogen bomb test in Bikini, contaminated fish were found only from the North Pacific, suggesting the possibility of separate populations in the two hemispheres (Nakamura, 1969).

In addition to the primary migratory trend, there are also lesser local movements reported. The area of high density off the central Mexican coast generally tends to expand westward seasonally reaching its maximum westward extent at about long. 130°W during the fourth quarter of the year (Kume and Joseph, 1969a, b). The region of high density around the Galapagos Islands during the second and third quarters expands eastward to the coast of Ecuador during the fourth and first quarters (Kume and Joseph, 1969a, b; Kume and Schaefer, 1966).

Nakamura (1949) mentions dense schools move from south to north along the coast of Vietnam in March and April.

In the western Pacific, Furukawa et al. (1958) report a gradual westward migration of fish from the vicinity of the Bonin Islands to the East China Sea in July and August where they stay until November after which a southward emigration takes place.

Migratory patterns in the Indian Ocean are unknown. The seasonal increase in density off East Africa during the northeast monsoon is believed to be a postspawning feeding migration (Williams, 1967; Merrett, 1971). The north-south type of seasonal movements that are typical in the Pacific are most evident off South Africa. A northward movement in the springtime (second quarter) is evident in the

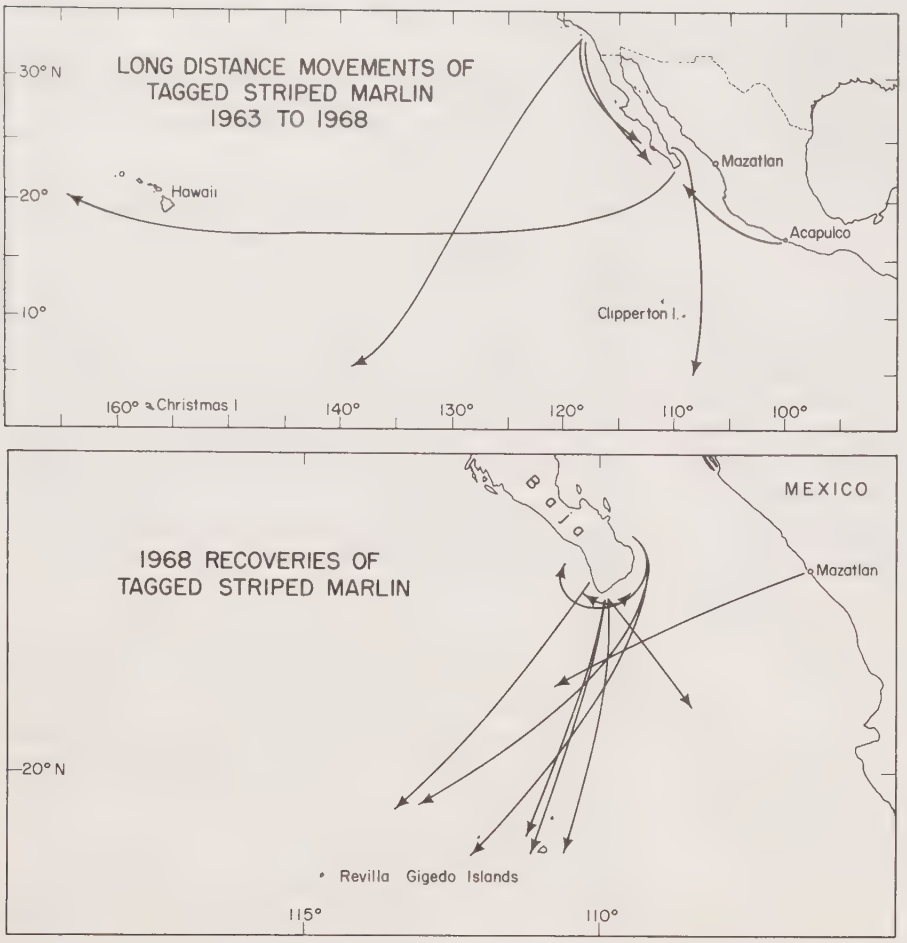

Figure 7.—Movements of tagged striped marlin in the eastern Pacific Ocean.

western Arabian Sea (Fisheries Agency of Japan, Research Division, 1969-72).

3.52 Schooling

Striped marlin, like the other istiophorids, do not form dense schools like the tuna, and the individuals are usually dispersed at wide intervals (Nakamura, 1949). Frequently, however, several fish are seen together; sometimes following one another, especially during the spawning season.

Surfacing is apparently more common when the wind and waves are high. When wind and current are moving in the same direction, the surface is calm and few fish are seen at the surface. When the wind runs counter to the current, high waves result, and fish are most often seen at the surface and are usually swimming in the direction of the wind, at least in Formosan waters (Nakamura, 1938).

When surfaced, the striped marlin usually is swimming very slowly with the upper caudal lobe above the surface and the dorsal fin retracted and not showing. This characteristic reportedly distinguishes them from swordfish which are unable to depress the dorsal fin and show both the dorsal and caudal fins when surfaced. Striped marlin swim faster and are less easily approached when surfaced than the swordfish (Philippi, 1887).

Little is known about how far the fish move vertically. Saito et al. (1972) report that striped marlin have been caught at 150- to 290-m depths by vertical longline experiments in Fiji waters.

For composition of stocks by size see also section 2.22. As mentioned previously, there is considerable variation in size composition between various regions and particularly between the northern and southern groups in the Pacific (see, for example, Howard and Ueyanagi, 1965; Koga, 1967; and Kume and Joseph, 1969b). As mentioned earlier, southern fish tend to be larger than northern fish throughout the Pacific. Size composition of striped marlin in the Indian Ocean resembles the North Pacific size distribution more than the South Pacific.

Striped marlin "schools" occur in waters in common with the schools of most of the Indo-Pacific scombroids, particularly albacore, yellowfin tuna, and bigeye tuna, *Thunnus obesus.*

3.53 Responses to stimuli

Very little is known of this subject as it relates to striped marlin. The possible response to temperature

has been mentioned previously. It may be pertinent to note here that when billfishes are caught by hook or harpoon, they first make several leaps into the air and then swim wildly in broad circles near the surface. Tunas, on the other hand, try to escape in a vertical direction by diving deep (Nakamura, 1949).

4 POPULATION

4.1 Structure

4.11 Sex ratio

Sex ratio of the population as a whole is unknown; but from the data of Williams (1967), Kume and Joseph (1969b), and Merrett (1971), females usually predominate in longline catches. The notable exception to this is on the spawning grounds, where males tend to predominate (Kume and Joseph, 1969b). The percentage of females tends to increase with size of fish (Kume and Joseph, 1969b). There is a tendency for spawning grounds to be dominated by larger fish than in nonspawning areas.

4.12 Age composition

Since age determination of individual fish is not possible at present, age composition of the population has not been studied. See 3.43 on growth rate.

4.13 Size composition

Size composition varies greatly between stocks and with seasons (see 3.52).

Size at first capture by tuna longline gear is about 80 cm eye-fork length.

Size at first maturity is between 140 and 160 cm eye-fork length.

Maximum size is probably about 290 cm eye-fork length or 258.6 kg (570 pounds).

See 1.31 for length-weight relationships.

4.2 Abundance and Density (of Population)

4.21 Average abundance

No data.

4.22 Changes in abundance

Relative abundance in terms of average CPUE (catch per unit of effort) for major ocean areas is shown in Table 5 for the years 1962-70. These data show no apparent trend for the eastern, northern or the Pacific Ocean at large, however, there is a general decline noted for the South Pacific and a slight decline in the Indian Ocean, the latter since 1966 (Fisheries Agency of Japan, Research Division, 1965-72).

Year-to-year changes in CPUE for the various

Table 5.—Catch statistics by major ocean areas of Japanese longline fishery for striped marlin for 1962-1970 (Fisheries Agency of Japan, Research Division, 1965-72).

	1962	1963	1964	1965	1966	1967	1968	1969	1970
Indian Ocean									
E[1]	68.4	57.3	68.9	79.9	89.6	126	119	101	78
C[2]	48	34	38	81	106	114	63	59	45
CPUE[3]	0.07	0.06	0.06	0.10	0.12	0.09	0.05	0.06	0.06
Whole Pacific									
E	290	337	283	288	301	306	286	306	282
C	287	338	508	421	351	406	506	323	450
CPUE	0.10	0.10	0.18	0.14	0.12	0.13	0.18	0.11	0.16
North Pacific									
E	156	154	140	153	150	193	165	169	163
C	144	123	210	156	98	159	154	101	242
CPUE	0.09	0.08	0.15	0.10	0.06	0.08	0.09	0.06	0.15
South Pacific									
E	109	131	81.2	92.2	104	70.6	71.0	70.1	67.7
C	59	49	28	29	30	17	14	14	32
CPUE	0.05	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.05
Eastern Pacific (E of 130°W)									
E	24.7	52.1	62.0	43.6	47.5	42.4	50.4	67.2	52.1
C	84	166	270	236	223	230	338	208	177
CPUE	0.34	0.32	0.44	0.54	0.47	0.54	0.67	0.31	0.34

[1]E = Effort in hooks $\times 10^6$.
[2]C = Catch $\times 10^3$.
[3]CPUE = Catch/100 hooks.

regions of the Pacific and Indian oceans are examined in section 5.41.

Seasonal variations in available stock are marked. See 2.22 on differential distribution. Kume and Joseph (1969a) have shown that there is a threefold seasonal fluctuation in CPUE for the various regions in the eastern Pacific.

4.23 Average density

No data.

4.24 Changes in density

No data.

4.3 Natality and Recruitment

4.31 Reproduction rates

Annual egg production rates have not been estimated. Little is known of fecundity relationship with fish size. See 3.15 for some estimates.

Nothing is known of survival rates of eggs and larvae because they are so rarely collected.

4.32 Factors affecting reproduction

No data.

4.33 Recruitment

There is little information pertaining to the variation in annual recruitment (see 3.43 and 4.24).

4.4 Mortality and Morbidity

No work has been done on mortality rates or causes of mortality.

4.5 Dynamics of Population (as a Whole)

No work has been done.

4.6 The Population in the Community and the Ecosystem

There is no specific information on this subject available; some general information on distribution and life history is presented in sections 2 and 3.

5 EXPLOITATION

5.1 Fishing Equipment

5.11 Gear

Virtually all of the commercial catch of striped marlin is by longlining. The harpoon fishery for billfishes is responsible for less than 5% of the total catch.

The longline gear aims largely at tunas and billfishes which are distributed at depths of around 100-150 m. The gear consists of mainline, float lines, branch lines, hooks, and buoys. The construction of the longline gear differs according to the species of fish sought, but Morita (1969) presents an example of a "standard" gear (Table 6). Several hundred of these units (each unit is referred to as a "basket") are joined in a series to make up a set. The gear is retrieved with a longline hauler.

Suda and Schaefer (1965) gave examples of the various types of longline gear presently in use (Table 7), and indicated that types 1 through 5 are the more typical ones in use. They also included the estimated hook depths for the different types of gear.

Billfishes are generally found closer to the sea surface than tunas. Therefore, in fishing primarily for billfishes, the longline gear is modified by shortening the float line and the branch lines and also by adding another buoy in the middle of the mainline section, the latter bringing the hooks closer to the surface. Furukawa et al. (1957) reported that for fishing billfishes in the East China Sea, the combined length

Table 6.—General form of tuna longline. (From Morita, 1969.)

Name of part	Material	Length	Number used for 1 basket
Mainline	Cremona (20S, 55×3×3)	250 m[1]	1
Branch line	Cremona (20S, 55×3×3)	11 m	4
Sekiyama	Steel wire (27 # 3×3) and hemp yarn coiled with thread No. 5)	5.5 m	4
Kanayama	Steel wire (27 #, 3×3, Type M)	3 m	4
Hook	Steel	3.8 sun[2]	4
Float Line	Cremona (20S, 55×3×3)	22 m	1
Flag buoy	Flag, bamboo, float (glass ball or synthetic resin ball)	—	1
Radio buoy			2 or 3 (for all basket)

[1]Length per one basket.
[2]1 sun = 3.03 cm.

Table 7.—Some examples of Japanese tuna longline gear. (From Suda and Schaefer, 1965.)

Type no.	1	2	3	4	5	6	7	8
A. The structure of one basket of the line (unit of length: meters)								
Length of mainline	300	300	300	300	300	245	360	350
Length of branch line								
Cotton or vinyl rope	13.5	10.5	12.0	11.5	12.0	12.0	14.5	12.0
Ganged wire leader	6.0	6.0	8.0	6.0	7.0	8.0	7.0	7.0
Wire leader	1.5	2.0	2.5	1.5	2.0	2.0	3.5	2.5
Length of float line	18.5	19.5	20.0	16.5	22.0	18.0	22.5	25.0
Number of hooks	5	5	5	5	5	4	4	6
B. The estimated maximum depth of each hook of the lines shown above								
No. 1 hook	86.5	85.0	89.5	82.5	90.0	84.5	113.5	92.5
2	127.5	126.0	130.5	123.5	131.0	123.0	169.5	136.5
3	148.5	147.0	151.5	144.5	152.0	123.0	169.5	168.5
4	127.5	126.0	130.5	123.5	131.0	84.5	113.5	168.5
5	86.5	85.0	89.5	82.5	90.0			136.5
6								92.5

of the float line and branch line should not exceed 30 m.

As for the amount of gear fished per day, Yoshida (1966) reported that "Vessels of 39 to 99 gross tons fish 210 to 355 baskets; vessels 100 to 190 gross tons fish 355 to 400 baskets; and vessels 200 to 500 tons fish 400 to 450 baskets." Suda and Schaefer (1965) reported that Japanese vessels in the eastern Pacific fished an average of 2,000 hooks (about 400 baskets) per set.

The basic construction of the longline gear has remained unchanged over the years. However, due to manpower problems some effort has been directed towards developing laborsaving devices in longlining. Two examples are the reel-type and tub-type of longlining.

In the reel-type, the mainline is continuously reeled onto a drum, while in the tub-type, the retrieved line is coiled into a large tub. Important advances in addition to the line hauler, include the "slow-conveyor" (for line setting and line hauling), the "guide stand" and "guide roller" (for leading line), gear-transporting conveyor system, line-winder system, etc. In using these methods, the branch lines are joined to the mainline by the use of snaps (Katsuo-Maguro Nenkan, 1969).

The principal bait used in longlining is frozen Pacific saury, *Cololabis saira*. Squid is also commonly used. Mackerel, *Scomber* sp., as well as mackerel scad, *Decapterus* sp., have been used as alternate bait. In addition, experiments are underway to utilize silver carp, *Hypophthalmichthys molitrix*, as well as artifical preparations (e.g., infused with extracts of saury) as longline bait.

Depending on the location, certain baits have been reported to have advantages in catching billfishes. For instance, in the East China Sea fishing grounds, live mackerel were believed effective and were used extensively. However, Furukawa et al. (1957) reported that using live or dead mackerel did not significantly affect the catches of white marlin (= black marlin), striped marlin, and broadbill.

The main piece of equipment in the harpoon fishery is the harpoon itself. The harpoon pole of oak is about 4 m long and at its tip is a three-pronged iron piece about 7 mm in diameter. The detachable harpoon of steel about 10 cm in length, connected to about 100 m of line, is placed over this iron tip. Recently the electric harpoon has been used in order to kill the fish quickly. When the harpoon enters the fish, a wire distributed along the harpoon line is charged with electricity.

5.12 Boats

The longline vessels fishing in the Indian and Pacific oceans for striped marlin are largely those from Japan. Other vessels are from Taiwan and Korea.

The details on the construction of longline vessels are given by Kanasashi (1960) and by Yoshida (1966). There are two types of longline vessels: those that use longline exclusively and those that use both longline and pole and line. The holds on longline vessels are not divided into small compartments to carry live bait. Thus, the hold space in the longliners is 20% to 40% greater than in the combination vessels.

Longline vessels are constructed of wood or steel; those larger than 100 gross tons are usually constructed of steel. Most of the longliners are 250 to 350 gross tons; at this stage of the fishery they appear to be the most economical and efficient size to operate. The specifications of typical longliners of this size class and those of some typical combination vessels are given in Yoshida (1966).

Other than the independently operating vessels, there is the mother ship operation in which several catcher boats are transported on the deck of a mother ship to the fishing grounds.

Small mother ships of 400 to 800 gross tons are able to carry only one portable catcher boat, but the larger 2,000- to 3,000-ton mother ships carry six catcher boats. The portable catcher boats measure about 15 m in length (Yoshida, 1966). To decrease the weight of the portable boats, recent constructions have been of fiber-reinforced plastic (FRP). The weight of a FRP boat is about 13 tons, or approximately two-thirds the weight of former catcher boats (Kazama, 1967).

Significant advances have also been made in preserving the catch of high-quality sashimi fish. Many vessels are equipped with refrigeration equipment capable of preserving the catch at very low temperatures of −40° to −45°C. In this way, the vessels are able to deliver fish in excellent condition and as a result, billfish prices have increased greatly in the Japanese market.

In addition, there have been advances in automating ship operations, fishing gear, and other equipment. Almost all longliners are equipped with fish detectors. Living conditions on the ships have also been improved considerably, and many vessels are now equipped with air conditioning for the crew's comfort (Katsuo-Maguro Nenkan, 1969).

Harpoon vessels are constructed with an extended prow where the harpooner is stationed. These vessels are constructed of wood, and range in size from about 10 to 40 tons. Billfishes taken by these vessels are kept in ice for delivery to the market.

5.2 Fishing Areas

5.21 General geographic distribution

The longline fishery now virtually covers the entire distribution of the species (see 2.1 and 2.22). The major sport fishing areas are southern California, Mexico, Panama, Ecuador, Peru, Chile, Hawaii, Tahiti, Fiji, New Zealand, Australia, and East Africa (not listed in order of importance).

5.22 Geographic ranges

See also 5.41.

Longlining is carried out across the high seas to within 5 miles of coastlines in places. The sport fishery is generally restricted to within about 75 miles of coastlines with the bulk of the fishing much closer.

The greatest fishing pressure is exerted in the North Equatorial Current in the Pacific and western Indian oceans, in the Kuroshio and Kuroshio extension, in the North Pacific Gyral northeast of the Hawaiian Islands, in the South Equatorial Current from about long. 90° to 140°W, and also off Mexico and Ecuador.

Regarding the development of the Japanese longline fishery, Suda and Schaefer (1965) report that prior to about 1952 the fishery was confined to the western and central Pacific. After this date it expanded into the Indian Ocean extending west of long. 80°E in 1954 and throughout the Indian Ocean by the end of 1955. In the Pacific, the fishery expanded eastward between lat. 10°N and lat. 10°S reaching 130°W by late 1956 and long. 85°W by 1961. After 1963 the fishery in the eastern Pacific expanded rapidly poleward, the northward expansion being primarily for striped marlin (Kume and Joseph, 1969a).

The fishing grounds for the Japanese harpoon fishery are located in the waters of Sanriku (off northeast of Honshu), around Izu, and East China Sea.

5.23 Depth range

Little has been written regarding fishing effort by depth range. Merrett (1968a) reports almost half of the striped marlin caught during experimental longlining off East Africa were caught over less than 1,000 fathoms even though most of the effort was expended beyond this depth contour.

5.24 Conditions of the grounds

See sections 2.1, 2.2, and 2.3.

5.3 Fishing Seasons

For sections 5.31, 5.32, and 5.33 see section 2.22.

The fishing season for the Japanese harpoon fishery in the waters of the Sanriku fishing ground extends from June to November with the peak occurring from July through September; in the Izu area from December to August with its peak from February through April; and in the East China Sea from December to February.

5.4 Fishing Operations and Results

5.41 Effort and intensity

Type of unit of effort: Detailed data on fishing effort and catch in the Japanese tuna longline fishery are published in the "Annual report of effort and catch statistics by area on Japanese tuna longline fishery" by the Research Division, Fisheries Agency of Japan. Fishing effort is reported in terms of number of operations and number of hooks fished; catch is reported in terms of number of fish. The statistics are reported on a monthly basis by 5° units.

Since 1967, Taiwan has also begun to publish data from their tuna longline fishery, following the same format as the Japanese publication. The Taiwan data are published annually in "Report on survey of production and marketing of Taiwan's tuna longline fishery" by the Taiwan Fisheries Bureau. Publication of effort and catch statistics of the Korean longline fishery started in 1970 in "Yearbook of catch and effort statistics on Korean tuna longline fishery" issued by the Office of Fisheries, Korea.

Landings per unit of fishing effort: As noted above, the catch statistics are reported in terms of numbers

of fish taken in the various unit areas. Landings by weight can be estimated from the data along with average body weight data.

Catches per unit of fishing effort: The catch per unit of effort (CPUE) can be obtained in terms of catch in numbers per 100 or 1,000 hooks fished. Strasburg (1970) studied year-to-year changes in CPUE of billfishes in the Pacific by analyzing the 1953-63 Japanese longline data for quadrangles measuring 20° of latitude and longitude. He noted a progressive decline over the years in the CPUE for the striped marlin of western and central South Pacific (lat. 20°-40°S) areas. Strasburg (1970) concluded that while some workers have attributed the decline in CPUE to heavy fishing, "It is impossible to determine its real cause without more information on various biological features related to migration, reproduction, age, and year classes."

Honma and Suzuki (1969) studied the apparent abundance of striped marlin in the principal fishing grounds in the Pacific (northwestern Pacific, eastern Pacific, and waters east of Australia) for the years 1960-66. They noted no apparent trends in CPUE in the northwestern Pacific and eastern Pacific grounds. On the other hand, for waters east of Australia, they reported a definite decreasing trend; the CPUE has been at a low level of around 0.1 fish per 100 hooks since 1964.

Of the striped marlin in the Indian Ocean, Kikawa et al. (1969) examined the annual changes in CPUE (number of fish per 1,000 hooks) based on data for the years 1962-67. They reported CPUE of about 0.6 fish per 1,000 hooks between 1962 and 1964, followed by an increase to about 1.0 in 1965-67. The authors concluded that "An increasing trend in the CPUE for striped marlin in this period may probably represent the increase in effectiveness in catching fish."

Fishing effort per unit area: Figure 8 shows the distribution of fishing effort of the Japanese tuna longline vessels in 1970. The effort, in terms of numbers of hooks fished, is shown by 5° quadrangles.

If we examine the data along with catch per unit area data of striped marlin (Fig. 9) it is apparent that the relatively large fishing effort in the eastern Pacific off Mexico and Ecuador is principally related to pursuit of striped marlin in those areas.

Total fishing intensity: The total fishing effort of the Japanese longline vessels in recent years (1965-69) for the Pacific and Indian oceans is estimated at about 400 million hooks fished per year. The efforts by areas are given in Table 5 (see 4.23).

Since 1963 there has been a significant increase in fishing effort in the eastern Pacific region. Correspondingly the fishing grounds for striped marlin also has increased during this period.

In the South Pacific region, however, effort has decreased from about 100 millin hooks in 1965-66 to around 70 million hooks beginning in 1967.

5.42 Selectivity

Small striped marlin under 80 cm eye-fork length are virtually never taken by longline.

Furukawa et al. (1958) have reported that striped marlin taken by harpooning in the East China Sea fishing grounds are relatively heavier (higher fatness index) than fish taken by longline.

5.43 Catches

Total annual yields: The FAO "Yearbook of fishery statistics" reports the total annual yields of striped marlin; Table 8 summarizes the 1970 catch (FAO, 1971). The recent total annual landings of striped marlin have been around 25,000 tons from the Pacific and Indian oceans.

Total annual yields from different fishing grounds: As seen in Table 8, the striped marlin catches are high in the eastern Pacific; the catch from this area comprises about one-half of the total Pacific

Table 8.—Catches of striped marlin by fishing areas for 1964-70. (From FAO, 1971.)

Area	1964	1965	1966	1967	1968	1969	1970
	In thousands of metric tons						
Indian Ocean	(2.4)	(3.8)	(3.8)	(6.2)	(3.8)	(4.3)	(3.1)
Western	1.2	2.1	3.2	4.9	2.2	2.5	2.1
Eastern	1.2	1.7	0.6	1.3	1.6	1.8	1.0
Pacific Ocean	(25.6)	(22.5)	(20.5)	(19.5)	(21.6)	(20.5)	(22.1)
Northwest	8.6	8.8	7.0	6.9	7.2	8.5	8.4
Eastern central	14.0	11.3	9.1	10.4	11.0	8.7	10.9
Southwest	1.4	1.3	2.3	0.9	1.7	1.6	1.6
Southeast	1.6	1.1	2.1	1.3	1.7	1.7	1.2
Total	28.0	26.3	24.3	25.7	25.4	24.8	25.2

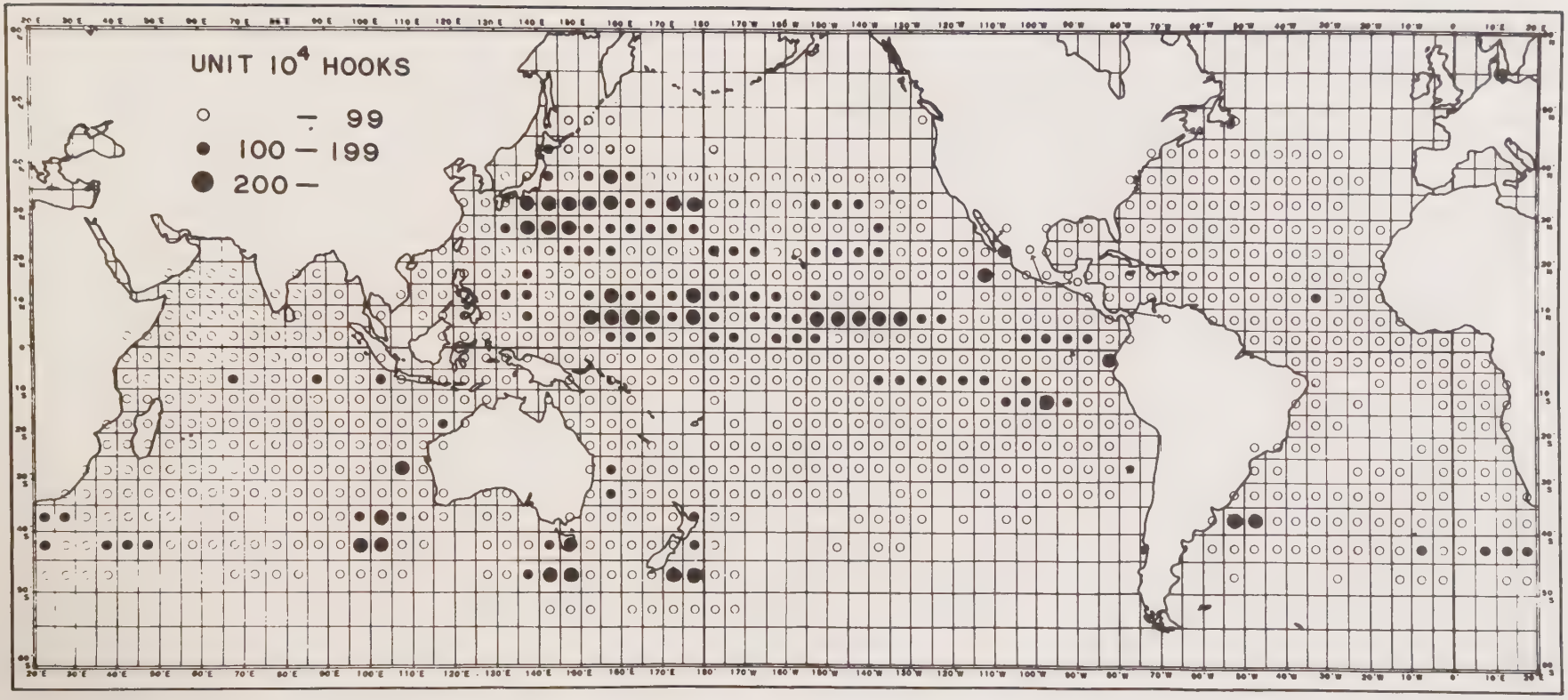

Figure 8.—Distribution of estimated total fishing effort, in numbers of hooks per unit area (1970).

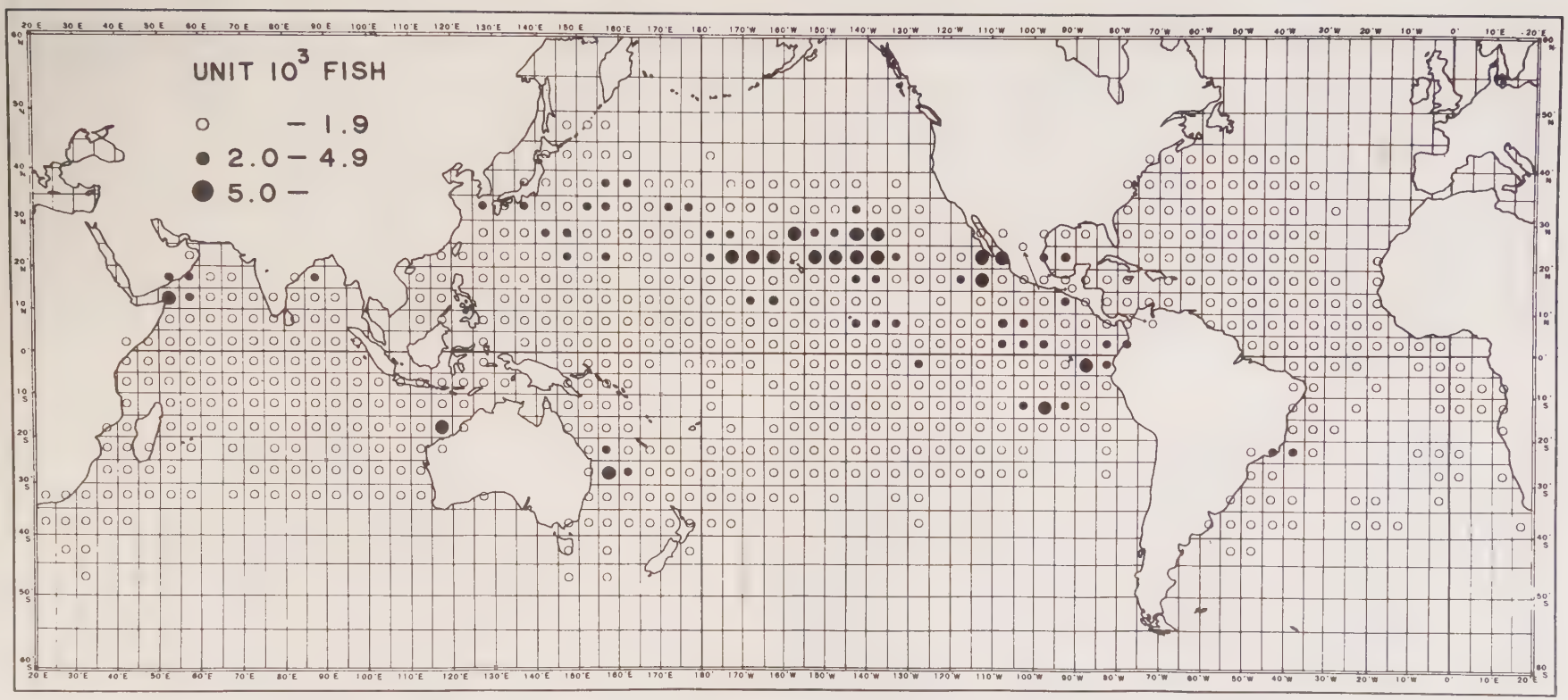

Figure 9.—Distribution of the catch of striped marlin in numbers per unit area (1970). Catch data in Atlantic Ocean area pertains to white marlin, *Tetrapturus albidus*.

landings. The Indian Ocean landings of striped marlin amount to approximately 20% of the Pacific landings.

Maximum equilibrium yield: Honma and Suzuki (1969) made some preliminary determinations of the maximum sustainable yield on the basis of 1960-66 data. They suggested that striped marlin catches in the Pacific can probably be increased about 60% over the recent average annual landings.

However, judging by the fact that catches have leveled off in recent years after fishing effort has virtually covered all of the known areas of striped marlin distribution, it appears that the present catches may be close to the maximum equilibrium yield level.

Obviously, further research is needed on this subject.

6 PROTECTION AND MANAGEMENT

6.1 Regulatory (Legislative) Measures

6.11 Limitation on reduction of total catch

The Japanese tuna longline fishery is regulated in terms of fleet size by the vessel licensing system. Licensing is reviewed at 5-yr intervals and fleet size is governed on the basis of the condition of the tuna resources. No increase in fleet size has been permitted since 1963. However, other countries such as Korea and Taiwan have increased the size of their longline fleet.

7 POND FISH CULTURE

Not applicable.

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